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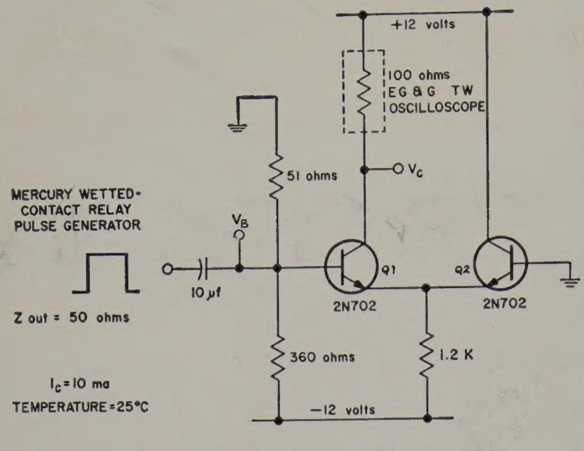
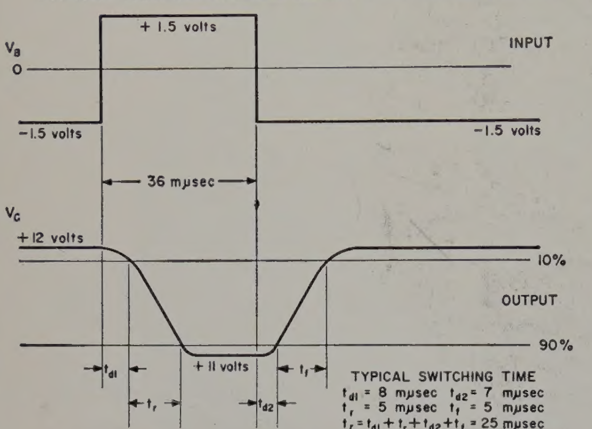
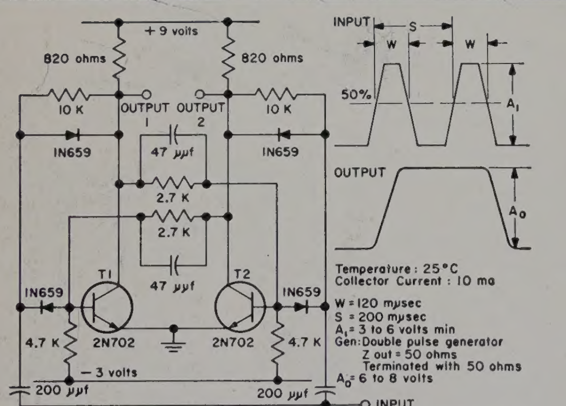


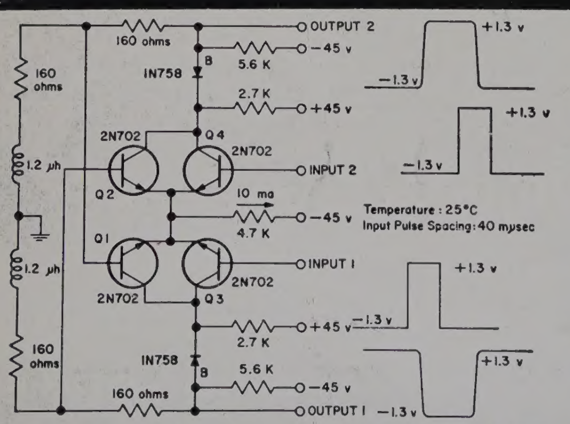
TYPICAL NON-SATURATED LOGIC SWITCHING CIRCUIT



TOTAL SWITCHING TIME NON-SATURATED CIRCUIT



TYPICAL CIRCUITRY FOR OBTAINING 5-MC REP RATE IN SATURATED FLIP-FLOP



TYPICAL CIRCUITRY FOR OBTAINING 25-MC REP RATE IN NON-SATURATED FLIP-FLOP

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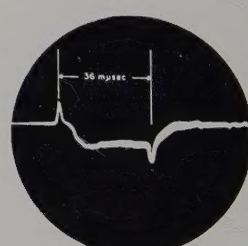

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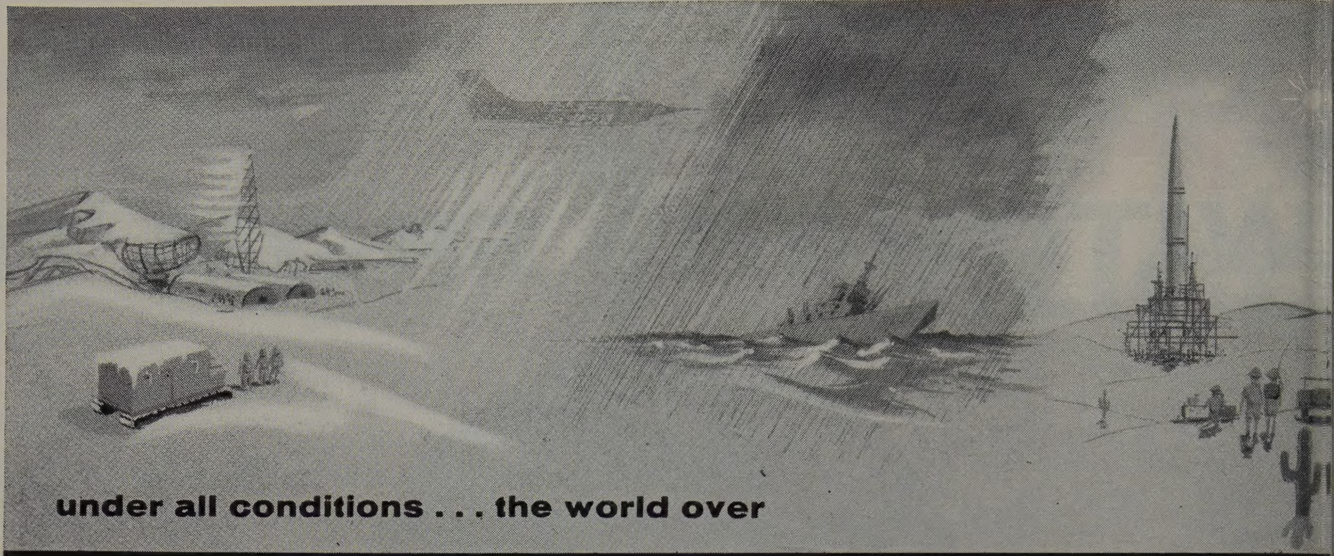

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Temperature — Humidity every Raytheon Bonded Silicon Diode receives three cycles of 15 minutes at −65°C and 15 minutes at +150°C; also four cycles totaling 32 hours at 95% relative humidity from 70°C to 25°C.

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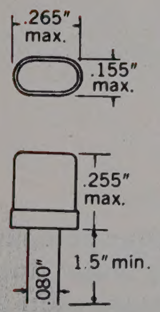
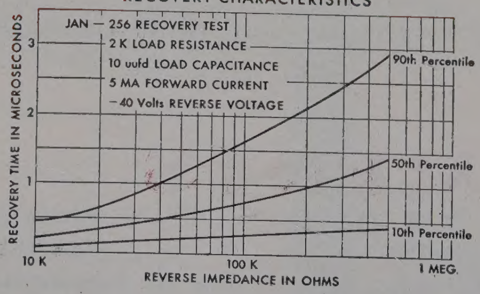
Type	PIV	I_F min. at 1v	I_{REV} max. at −10v	I_{REV} max. μA at specified voltage			I_O max. mA	
		mA	μA	volts	25°C	150°C	25°C	150°C
1N300	15	15	.001	10	0.001	2.0	65	18
1N300A	15	30	.001	10	0.001	2.0	80	25
1N300B	15	50	.001	10	0.001	2.0	100	30
1N432	40	10	.005	10	0.005	3.0	55	15
1N432A	40	20	.005	10	0.005	3.0	70	22
1N432B	40	50	.005	10	0.005	3.0	85	30
1N301	70	5	.01	50	0.05	8.0	45	12
1N301A	70	18	.01	50	0.05	8.0	65	20
1N301B	70	50	.01	50	0.05	8.0	75	25
1N460	90	5	.01	75	0.1	10.0	45	12
1N460A	90	15	.01	75	0.1	10.0	60	18
1N460B	90	50	.01	75	0.1	10.0	70	25
1N303	125	3	.01	100	0.1	14.0	40	10
1N303A	125	12	.01	100	0.1	14.0	55	16

Type	PIV	I_F min. at 1v	I_{REV} max. at −10v	I_{REV} max. μA at specified voltage			I_O max. mA	
		mA	μA	volts	25°C	150°C	25°C	150°C
1N303B	125	50	.01	100	0.1	14.0	65	20
1N433	145	3	.01	125	0.1	16.0	40	10
1N433A	145	10	.01	125	0.1	16.0	50	16
1N433B	145	50	.01	125	0.1	16.0	60	20
1N434	180	2	.01	150	0.1	18.0	35	10
1N434A	180	7	.01	150	0.1	18.0	45	15
1N434B	180	20	.01	150	0.1	18.0	60	20
1N302	225	1	.01	200	0.2	20.0	30	8
1N302A	225	5	.01	200	0.2	20.0	40	13
1N302B	225	20	.01	200	0.2	20.0	55	20
CK863	300	1	.01	275	0.3	30.0	20	6
CK863A	300	3	.01	275	0.3	30.0	30	8
CK863B	300	20	.01	275	0.3	30.0	50	15

Ratings at 25°C unless otherwise indicated





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SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

August 1959 Vol. 2 No. 8

Front Cover

Hughes Semiconductor Division diode for use in parametric amplifiers and microwave applications such as switching and harmonic generation. Production models HPA-2800 and HPA-2810 have a nominal cutoff frequency of 70,000 *mc* at maximum back bias with a nominal zero-bias capacitance of 2.5 micro-microfarads.

SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp. Executive and Editorial Offices: 300 West 43rd Street, New York 36, N. Y. Telephone: JUdson 2-4460. Subscription price: \$6.00 for 12 issues in the United States, U. S. Possessions, APO, FPO, Canada and Mexico, \$8.00 for 12 issues. All others: 12 issues \$10.00. Single Copy 75¢. Accepted as controlled circulation publication at Bristol, Conn.

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Editorial . . .

Esaki or "Tunnel" Diodes

With the disclosure of an article in the Physical Review, *Vol. 109, P603, 1958* entitled "New Phenomena in Narrow Germanium *p-n* Junctions" by L. Esaki, new properties of *p-n* junctions were uncovered. The Esaki or "tunnel" diode, a name that has been applied by virtue of the tunneling action of carriers that occurs within the junction of the device, is currently being investigated by many companies to determine its present and future application potential.

The tunnel diode undoubtedly represents the most important recent development in the semiconductor devices field. It is obtained with degenerate doping (concentrations of the order of 10^{17}/cc) of the *p* and *n* regions. The Fermi levels in thermodynamic equilibrium occur respectively inside the valence and inside the conduction band and the $I - V$ characteristic presents a region with negative slope in the ranges ~ 0.05 to ~ 0.2 Volt and ~ 0.3 to ~ 0 mA. As a result the diode may be used as a short circuit stable device, for purposes of switching, amplification or oscillation. The diode may operate at temperature well beyond that of ordinary *p-n* junction diodes (for example beyond 100° C in the case of germanium) and possess switching times of the order of fractions of microseconds. Similarly they may be used to amplify signals of frequencies up to 1000 *mc* and higher, with low noise figure (values of ~ 4 *db* were indicated at 30 *mc*). Germanium, indium-antimonide, gallium arsenide, silicon may be used for its construction.

In a recent article in the Proceedings of the IRE, July 1959, by H. S. Sommers, Jr., the theoretical highest frequency of oscillation of the diode was shown to be:

$$f_o = \frac{(R/r_t)^{1/2}}{2\pi RC}$$

where R is the negative resistance of the diode, C is the junction transition capacitance, r_t is the dissipation resistance of the diode.

The author further reports that oscillations of 1.4 *kmc* have been observed utilizing this device and harmonics greater than 4 *kmc* have been generated. Besides its capability of oscillating in the kilomegacycle region, other applications of the device have been suggested such as a self-excited converter, and a negative-resistance amplifier with a good noise figure.

Reporting on the amplifier application, K.K.W. Chang reveals data on measurements made in this mode of operation in the same issue of the Proceedings. Amplifier circuits have been built at operating frequencies of 30, 66, and 80 megacycles. Data reported indicates power gains of 40 decibels, at a bandwidth of 0.19 megacycles and a resultant noise figure of 6.3 decibels.

The advent of the Esaki diode adds another member of semiconductor devices capable of operating in the microwave region. It will be interesting to view future strides made in the development and application of the "Tunnel" diode.

The 1959 Solid State Devices Research Conference

Principal topics discussed at the recent Solid State Devices Research Conference were tunnel diodes, *p-n-p-n* devices, parametric amplifiers, luminescent, thermoelectric and cryogenic devices.

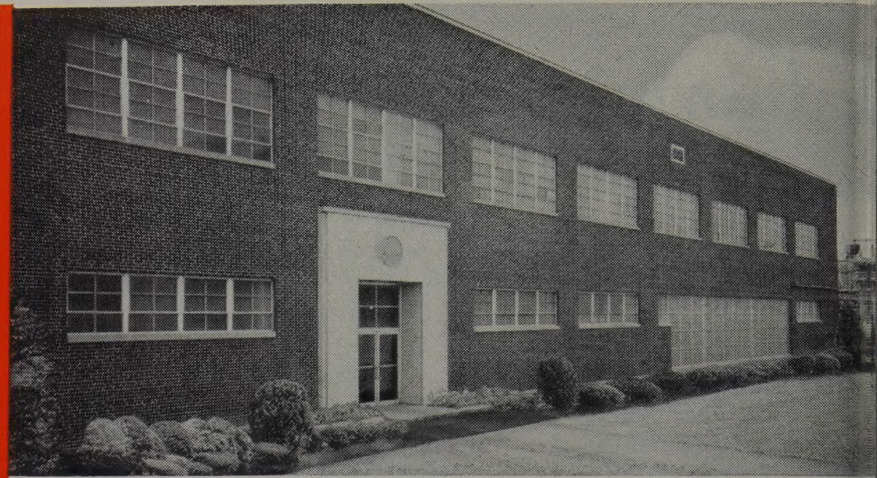
Interesting theoretical, and practical developments were indicated in the field of *p-n-p-n* devices. In particular the construction of devices with low on-off as well as off-on switching times, of a stepping transistor (obtained applying a difference of potential across one of the base regions) and of diodes with short-circuited emitter and base I terminals were discussed.

In the field of parametric amplifiers papers of applied nature were presented. In particular, the rigorous solution of the potential distribution in a graded *p-n* junction, the theory of parametric amplification in periodically loaded transmission lines, and the theory of noise generation in the depletion layer of variable capacitance diodes due to statistical fluctuations of the ionization levels, were given. In addition, the construction of the very high frequency silicon diodes (cutoff frequency of the order of 300 *kmc*) with limited spread of capacitance values and the construction of travelling wave parametric amplifiers were discussed.

Space does not permit reporting on the many other interesting papers which contributed to making the 1959 Solid State Devices Research Conference a very worthwhile meeting.

Samuel L. Marshall

MERCK HAS ALL FOUR FORMS OF



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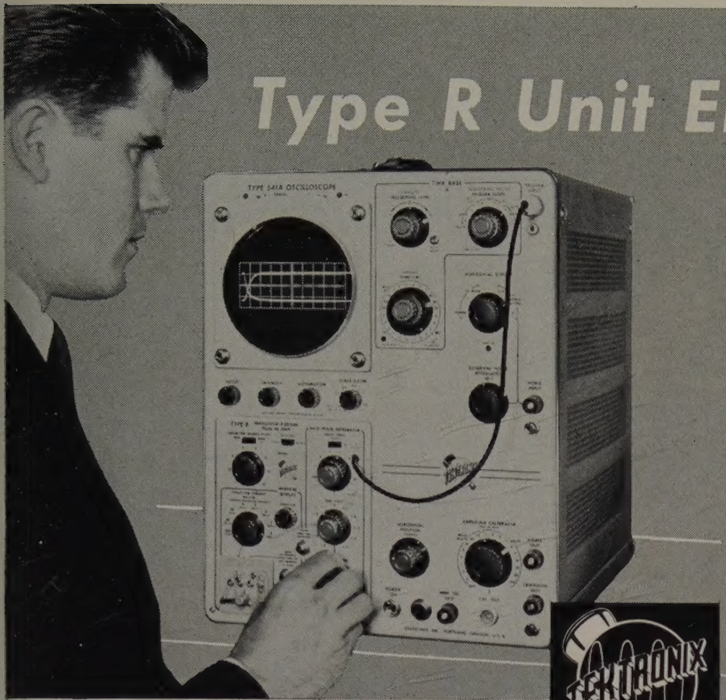

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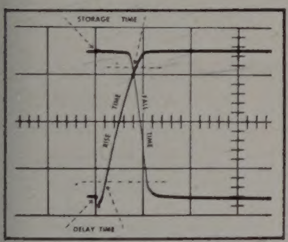
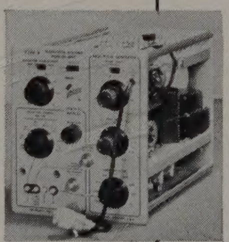
Type R Transistor-Risetime Unit **$300**



The Type R Unit can trigger the Oscilloscope sweep either on the start of the test pulse only, or on both the start and finish to display delay, rise, storage, and fall times simultaneously.



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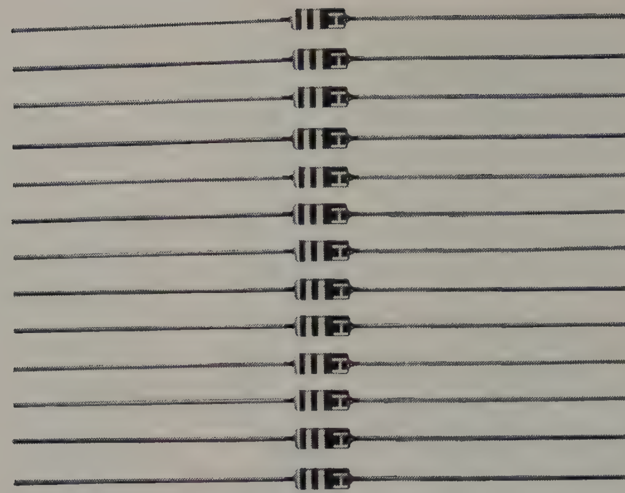

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RATINGS AND SPECIFICATIONS: Absolute Maximum Ratings at 25° C.

JEDEC No.	PIV	RMS Volts	Max. Average Rectified Current mA	Max. Surge Current One Cycle (amp)	JEDEC No.	PIV	RMS Volts	Max. Average Rectified Current mA	Max. Surge Current One Cycle (amp)
1N846	50	35	200	2A	1N868	50	35	100	1.0
1N847	100	70	200	2A	1N869	100	70	100	1.0
1N848	200	140	200	2A	1N870	200	140	100	1.0
1N849	300	210	200	2A	1N871	300	210	100	1.0
1N850	400	280	200	2A	1N872	400	280	100	1.0
1N851	500	350	200	2A	1N873	500	350	100	1.0
1N852	600	420	200	2A	1N874	600	420	100	1.0
1N853	700	490	200	2A	1N875	700	490	100	1.0
1N854	800	560	200	2A	1N876	800	560	100	1.0
1N855	900	630	200	2A	1N877	900	630	100	1.0
1N856	1000	700	200	2A	1N878	1000	700	100	1.0
1N857	50	35	150	1.5	1N879	50	35	50	.5
1N858	100	70	150	1.5	1N880	100	70	50	.5
1N859	200	140	150	1.5	1N881	200	140	50	.5
1N860	300	210	150	1.5	1N882	300	210	50	.5
1N861	400	280	150	1.5	1N883	400	280	50	.5
1N862	500	350	150	1.5	1N884	500	350	50	.5
1N863	600	420	150	1.5	1N885	600	420	50	.5
1N864	700	490	150	1.5	1N886	700	490	50	.5
1N865	800	560	150	1.5	1N887	800	560	50	.5
1N866	900	630	150	1.5	1N888	900	630	50	.5
1N867	1000	70[illegible]	[illegible]	1.5	1N889	1000	700	50	.5

Storage temp. —65° to +200°C.
Max. Leakage current full cycle average 20μA.

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APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST No. 10

Transistor Circuits; Bendix Aviation Corp., Long Branch, New Jersey.

This application note provides the engineer with sixteen circuits utilizing semiconductor devices, and covering a variety of applications. Titles of circuits provided in the original application note are listed below:

1 — Transformerless Intercom
2 — Transistor Class B Bias Circuit
3 — Low Cost Transistorized Megaphone
4 — Transistorized Light Flasher
5 — Transistorized Power Megaphone
6 — Photo—Flash Circuits
7 — Boat Horn and Siren Circuit
8 — TV Deflection Circuit
9 — Hi-Fi Stereo Preamplifier Frequency Response 20-20 KC
10 — High Efficiency 2 watt Portable Amplifier
11 — 20 Watt Hi-Fi Amplifier
12 — Low Cost Hi-Fi Amplifier
13 — Transistor Power Pack
14 — 300 V DC Regulated Supply
15 — Transistorized Modulator
16 — Surge Protected DC-DC Converter

Typical of the circuits described is that shown in *Fig. 10.1*. Here a Bendix 2N1073B is used in a TV horizontal deflection circuit. This transistor has a very fast switching time and a high gain. The saturation resistance is very low for good linearity. The B-201 rectifier is a high speed, low forward resistance drop diode for the reverse yoke current swing.

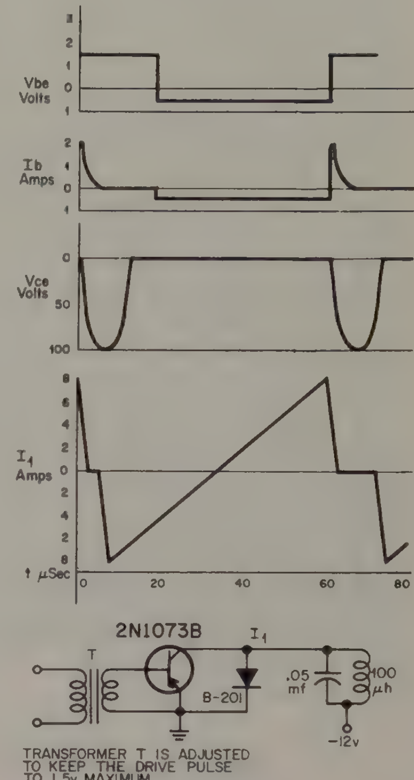

Fig. 10.1—TV deflection circuit.

Figure 10.2 illustrates another of the circuits described. This is a high voltage supply where size and regulation are important factors. The regulation of this supply is typically ±1% from 0 to 200 *ma* d-c, with an output ripple of less than 3 millivolts peak-to-peak.

Circle 198 on Reader Service Card

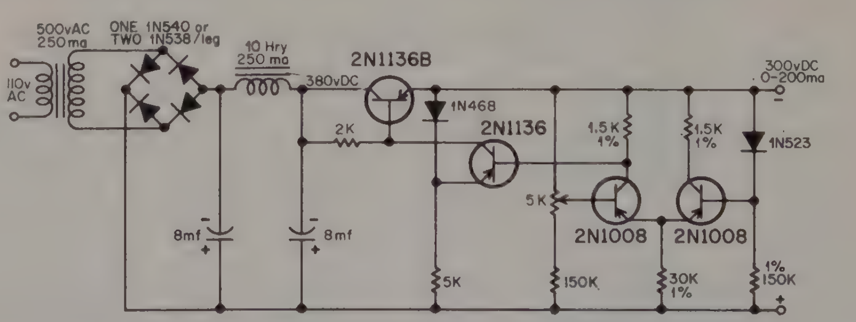

Fig. 10.2—300 volt d-c regulated power supply.

APPLICATIONS ENGINEERING DIGEST No. 11

Magnetic Rectifier Controls; Fairfield Engineering Corp., Springdale, Conn.

Magnetic Rectifier Controls (MRC's) to drive General Electric's new silicon controlled rectifiers in power control and servo systems are Fairfield Engineering's most recent contribution to this new and revolutionary method of controlling power. Applicable in systems ranging in power from a few watts to many kilowatts, the new MRC units

with silicon controlled rectifiers offe stability, uniformity, and reliability c magnetic amplifiers at reductions i size and weight.

A simple half-wave MRC power con trol circuit is illustrated in Figure *11.* This is *not* a simplified schematic; it i the complete power control circuit, cap able of delivering up to 2 kilowatts c controlled *d-c* output power! The *d-* output is smoothly controllable fron

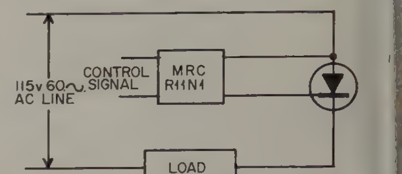

Fig. 11.1—Half-wave MRC power con trol circuit.

zero to maximum by means of a smal *d-c* control signal current applied to a control winding in the MRC unit, and the control thus established is stable accurate, and almost completely inde pendent of any variations in the charac teristics of the silicon controlle rectifiers.

MRC Theory Of Operation

Figure 11.2 is a schematic circuit dia gram of the internal wiring of the general purpose MRC, Model R27N2. It contains two MA's (Magnetic Ampli fiers), separately excited by individua secondary windings on the input trans former. In addition, there is a center

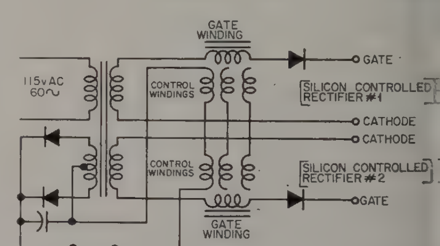

Fig. 11.2—Wiring diagram of Model R27N2 MRC.

tapped secondary winding for the internal bias supply. Each MA has three control windings, the control windings being connected in series, as shown, with one pair connected to a terminal of the internal, full-wave rectified, bias supply. In operation the input transformer applies *a-c* to each MA, and diodes in series with the MA's rectify the applied *a-c* to develop a *d-c* component which saturates the MA cores. Half-wave rectified current therefore flows in the gate-cathode circuit of the silicon controlled rectifiers.

By closing the bias circuit with an external resistor, *d-c* can be made to flow in the bias windings until the net *d-c* in each MA is zero. In this condition, the MA cores are unsaturated, and the gate windings present a high impedance, effectively an open circuit, to the *a-c* excitation. If now a small *d-c* signal current is injected into a free control winding, there will be a point

in the applied a-c cycle where the MA core saturates. At this point in the cycle the MA gate winding suddenly becomes a low impedance, practically a short circuit, and the applied a-c input appears instantaneously at the gate of the silicon controlled rectifiers.

Circle 199 on Reader Service Card

APPLICATIONS ENGINEERING DIGEST No. 12

Shockley 4 Layer Transistor Diode; Shockley Transistor Corp., Palo Alto, California.

The Transistor Diode is a self-actuated silicon switch with operating characteristics based on the principles of transistor action. It is a two terminal device with two stable states: (1) an "open" or high resistance state of more than one megohm, and (2) a "closed" or low resistance state of a few ohms. The device is switched from one state to the other by controlling the voltage across it, and the current passing through it.

Because the switching properties of the transistor diode closely approach those of the ideal switch, it is finding applications in many fields. In addition to its advantages as a semiconductor switch, it provides the unusual combination of power handling ability and fast switching. Some of its present applications include pulse generators and amplifiers, oscillators, relay alarm circuits, ring counters, detonator firing circuits, magnetron and sonar pulsing, telephone switching, and computer applications such as magnetic core driving. It has been used in replacing relays, thyratrons, gas diodes, and switching transistors.

Typical pulse generator and amplifier circuits are shown in *Figs. 12.1* and *12.2.*

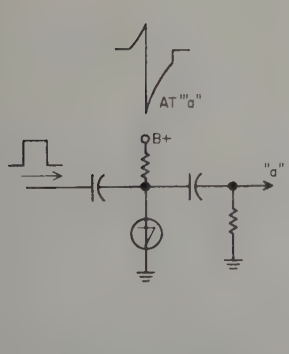

Fig. 12.1—Simple pulse generator with low impedance input.

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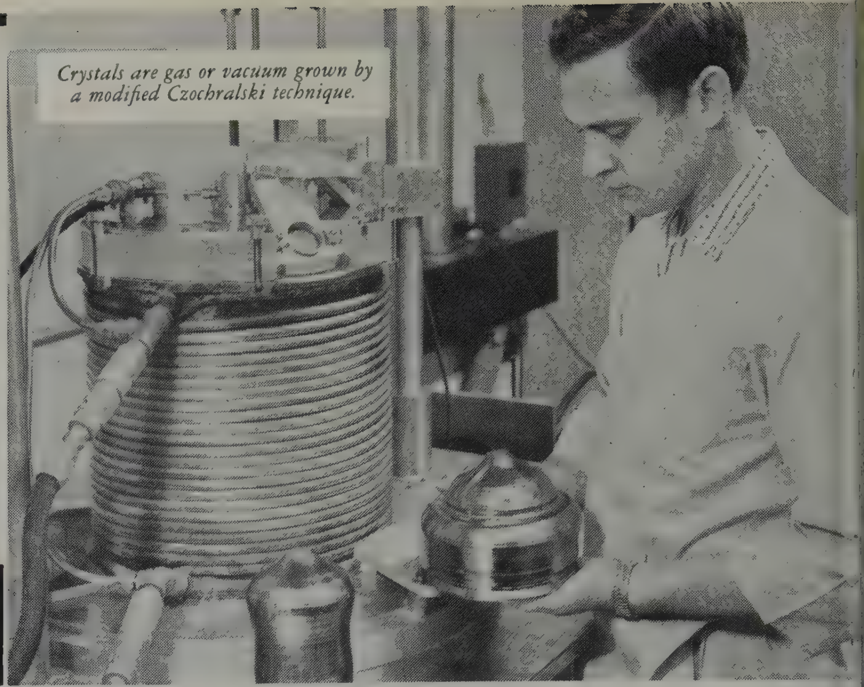
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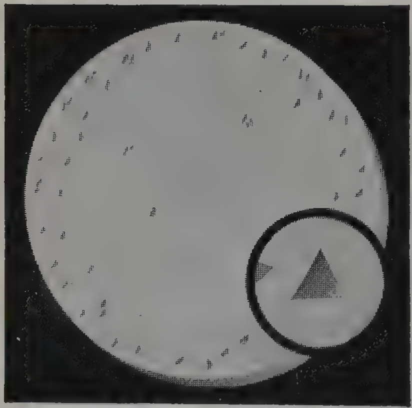
Dislocation density, Knapic silicon monocrystals. Crystal diameter 1/10" to 3/8"—None; 3/8" to 3/4"—less than 10 per sq. cm.; 3/4" to 1-1/4"—less than 100 per sq. cm.; 1-1/2" to 2" less than 1000 per sq. cm.

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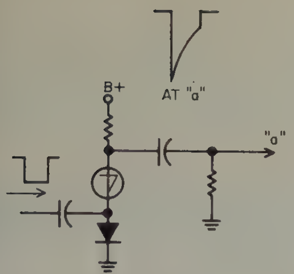

Fig. 12.2 — Triggered pulse generator with high impedance input.

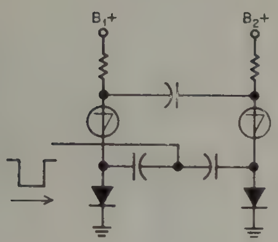

Fig. 12.3—Flip-flop circuit.

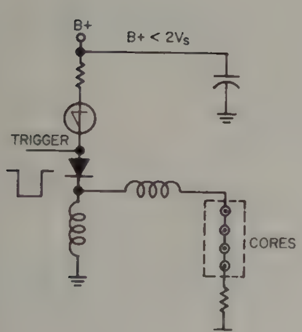

Fig. 12.4—Core drive circuit.

A typical flip-flop circuit is pictured in *Figs. 12.3.* The circuit shown may be triggered from one to the other of two conditions. Depending on the value of the resistors and the supply voltage, the circuit may be astable, monostable, or bistable in its action.

Figure 12.4 shows a magnetic core drive circuit. The transistor diode can be used for core driving circuits where the current pulse delivered to the load must usually be large and of short duration. Some pulse shaping elements may be necessary in such a circuit. A typical circuit is illustrated.

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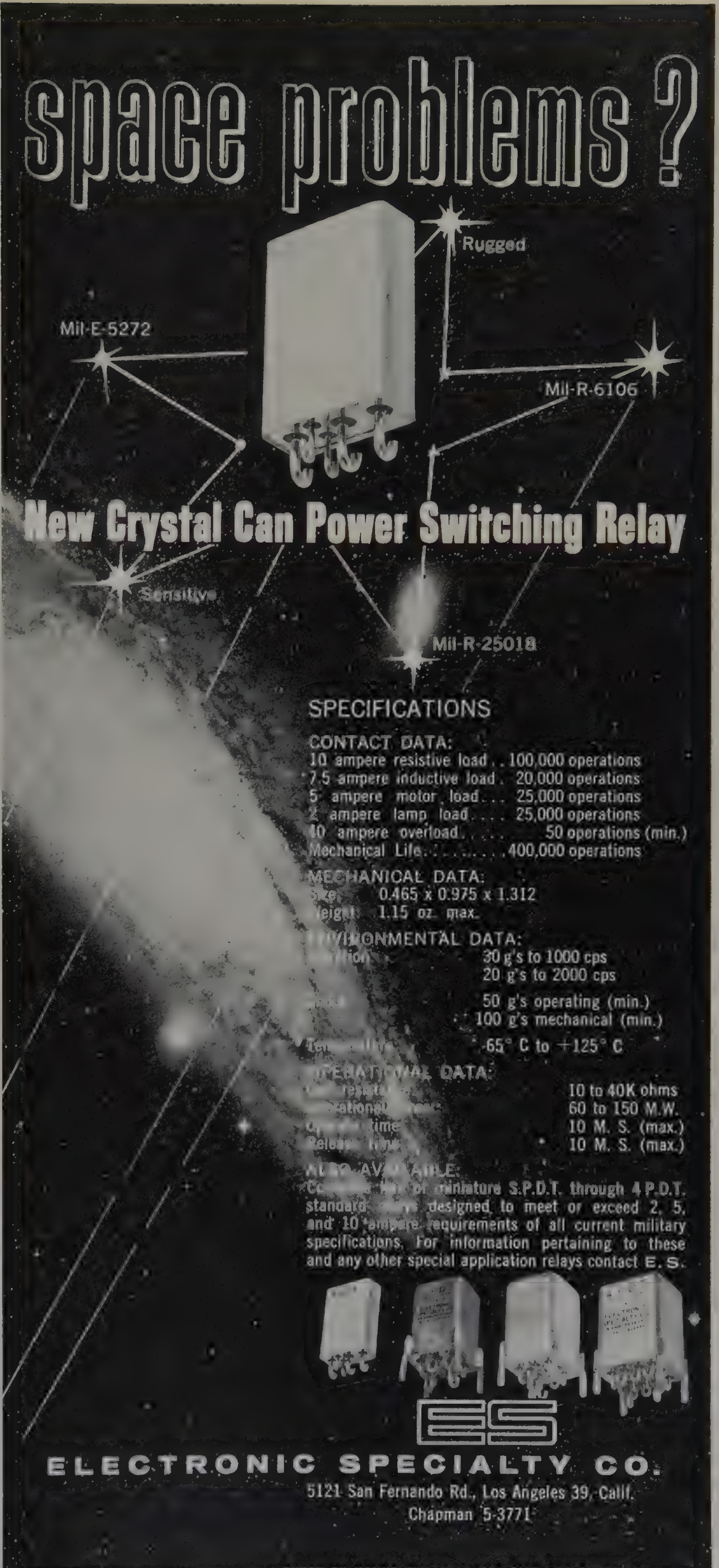

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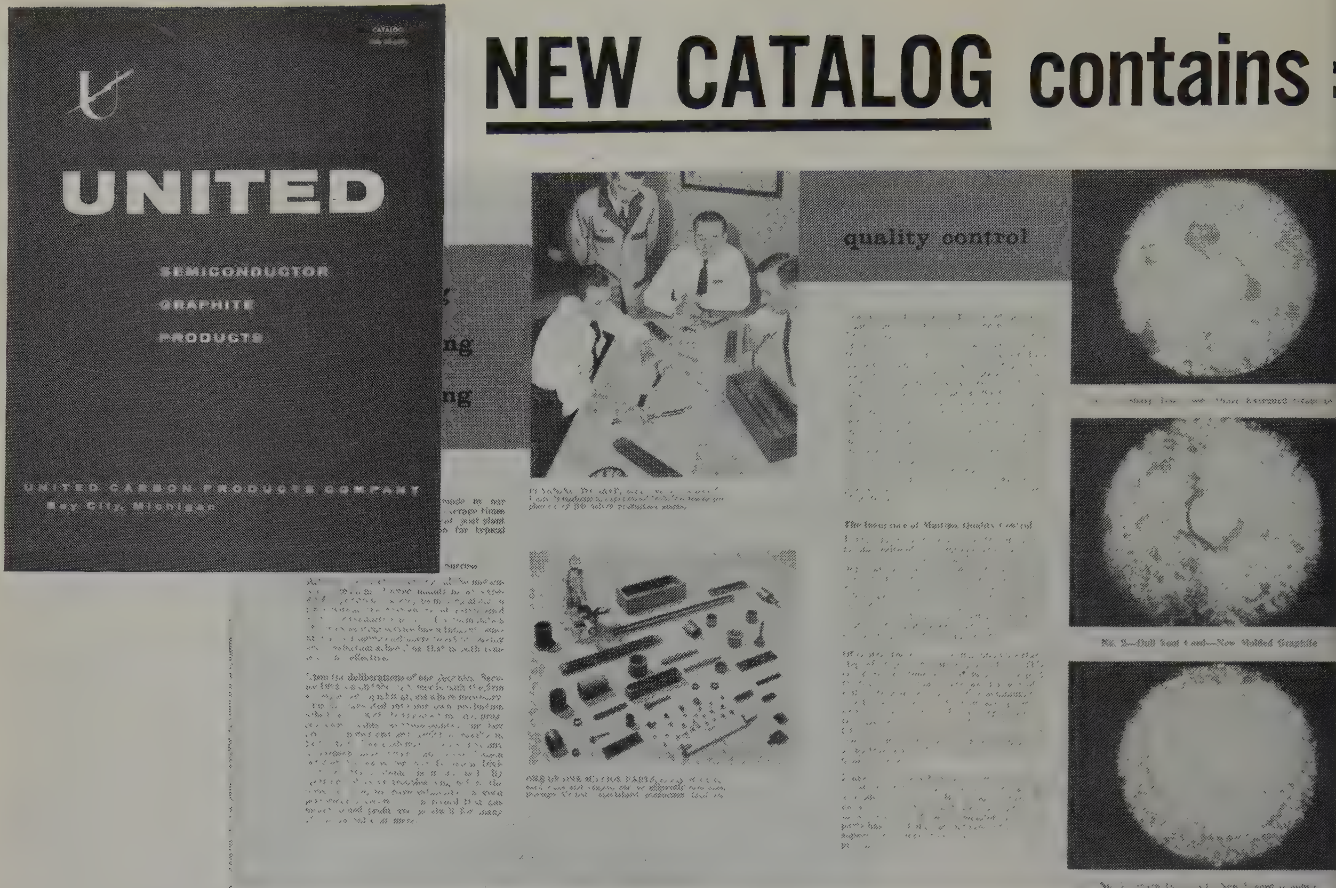

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Transistor TV Vertical Deflection

M. J. HELLSTROM*

[Tear sheets of this article are available on written request]

I. Introduction

TELEVISION VERTICAL DEFLECTION CIRCUITS using transistors and direct coupling to the deflection yoke have been described in the literature. [1], [2] These require two power transistors or perhaps one power transistor and two low level units. Although techniques for compensation for the large average flux in the yoke are known, [1], [2] they suffer from difficulties with linearity, raster distortion and power consumption. A circuit which uses direct coupling to the yoke requires approximately twice as much power from the battery as does one using *a-c* coupling to the yoke. This is illustrated in *Fig. 1* which shows graphically the relative power consumption and its division between the yoke and output transistor. Since power is a prime consideration in a portable television receiver which is to be operated from a battery, *a-c* coupling is considered as an important design objective. This objective has been accomplished in circuits[3] requiring at least three transistors to overcome the non-linearizing effects of the coupling transformer or choke. The *a-c* coupled circuit described here uses two transistors, one of which is a power unit, and a diode. To aid in understanding some of the problems involved and the evolution of this circuit, the circuit requirements will be studied, starting with the output stage.

II. Circuit Requirements

Output Stage

If there is a fixed space available on the yoke for the vertical deflection winding, then the magnitude of the impedance of the yoke may be varied over a wide range but the time constant remains constant.[4] The impedance level which should be used at the collector of the output stage is then determined by the collector voltage rating of the output transistor. For presently available transistors this is from 40 to 60 volts. The impedance level of the yokes used in current vacuum tube receivers is suitable for coupling to the output stage without appreciable transformation. Therefore, we will consider such a yoke with a resistance of 45 ohms and an inductance of 45 millihenrys and which requires a peak-to-peak current of 400 milliamperes for full deflection. If the current gain of the output stage, including its biasing and stabilizing network, is 40, then the base drive must be a 10-milliampere peak-to-peak current ramp. Suppose an attempt is made to drive the output stage from a charging circuit consisting of a series resistance and capacitance. In order to preserve linearity, the average charging current must be much larger than the base current required by the output stage. Thus, the charging current i_{sw} in *Fig. 2,* must be on the order of 100 milliamperes. If the charging source is 12 volts, the power wasted in the sweep resistance, R, is 1.2 watts. In comparison with the minimum power that can be dissipated in the 45 ohm yoke at full sweep, i.e., 0.6 watts, this clearly is excessive.

Another serious problem is introduced by the large charge stored on the sweep capacitor, C, during the 16 milliseconds of sweep. This charge of 1.6×10^{-3} coulombs must be removed during a retrace time of

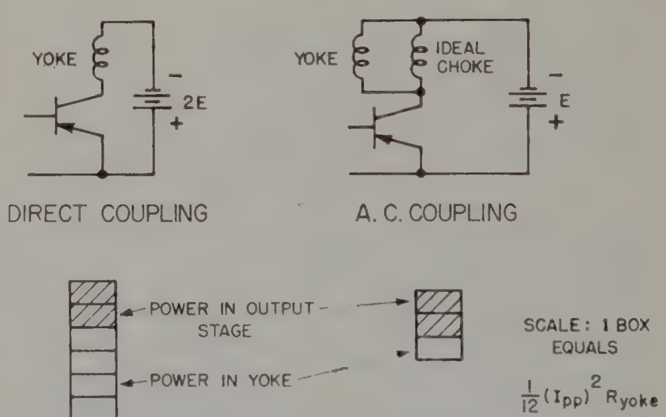


Fig. 1 — Output stage power consumption for ideal *d-c* and *a-c* coupling.

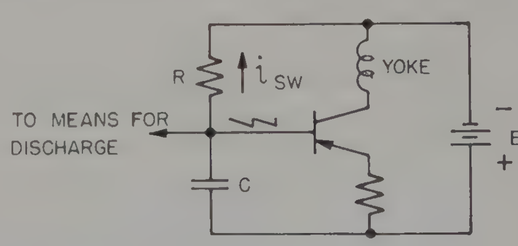


Fig. 2 — An *R-C* driven output stage.

*Supervising Engineer, Westinghouse Electric Corp.,
Advanced Development Laboratory,
Television-Radio Division,
Metuchen, New Jersey

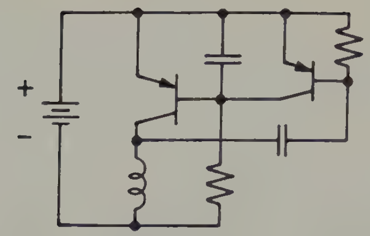


Fig. 3 — Multivibrator type vertical oscillator using two power transistors.

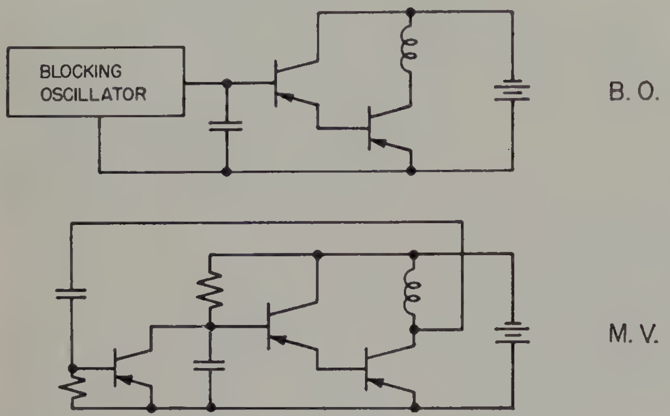


Fig. 4 — Three transistor vertical deflection circuits.

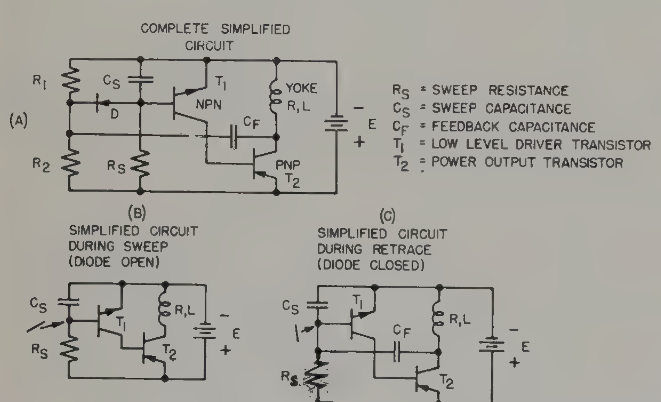


Fig. 5 — Simplified two transistor vertical deflection circuit.

approximately one millisecond. Since the device which is used to discharge C must then carry an average current of 1.6 amperes, a power transistor is required. Such a circuit might be made as shown in *Fig. 3.*

In order to reduce the power dissipated in the sweep resistance, and to decrease the charge transferred into and out of the sweep capacitor to a level that can be handled by a low-power transistor, a driver stage can be inserted between the R-C charge elements and the output transistor. Because of the current gain of this low-power driver stage, the 10-milliampere load on the sweep capacitor is reduced to, say, 200 microamperes.

Two schemes of this type are outlined in *Fig. 4.* One is a multivibrator arrangement and the other uses a blocking oscillator to discharge the sweep capacitor.

An alternative arrangement is to use some of the energy stored in the yoke during the sweep time to alter the charge on the sweep capacitor during retrace time. This is accomplished in the circuit arrangement shown in its simplest form in *Fig. 5.* One power transistor, one low-level transistor, and a diode are used. The fundamentals of its operation will be described for the simple circuit of *Fig. 5.* Then the complicating factors relating to thermal stabilization, linearity, *a-c* coupling, and other practical problems will be discussed.

III. Basic Circuit

Referring to *Fig. 5A,* if we look in on the operation at a point during the sweep interval, then the voltage across the sweep capacitor, C_S, is less than the voltage across resistance R_1, and the diode, D, is open. The loading effect of C_F, R_1, and R_2 on the collector of the output transistor, T_2, may be neglected so that the circuit of *Fig. 5B* applies during this sweep interval when the diode is open. Notice that none of the elements R_1, R_2, C_F, or D is present in Fig. 5B. The sweep capacitor, C_S, is charging toward the supply voltage, E, through sweep resistance R_S, This rising voltage is applied to the base of the driver transistor, T_1, producing an increasing base current and hence collector (and yoke) current in the output transistor, T_2. Thus during the sweep time, when the diode is open, the circuit consists of two common emitter amplifiers in cascade driven by an R_S—C_S charge combination.

Returning now to *Fig. 5A,* when the voltage across the sweep capacitor reaches that level set by the divider R_1 and R_2, the diode closes and connects a positive feedback path from the collector of the output stage via the feedback capacitor, C_F, to the base of the driver stage. An oscillation begins, involving the inductance of the yoke and the capacitance C_F and C_S in series. Initially the current path is through the diode in its forward direction. As long as the diode is conducting and represents a low impedance the equivalent circuit is that shown in *Fig. 5C.* The flow of current in the forward direction of the diode discharges the sweep capacitor very quickly. When the current attempts to reverse its direction due to the tuned oscillation, the diode opens up and the circuit is again in its linear amplifier mode pictured in *Fig. 5B.* The sweep capacitor then charges through R_S commencing the sweep period again.

A-C Coupling to Yoke

It was stated in the introduction that *a-c* coupling to the yoke is a principal consideration. The problems involved in doing this with an inductor of reasonable size are chiefly linearity and efficiency. Since the yoke has the correct impedance there is no appreciable transformation of level required. Hence either a choke or a unity turns ratio transformer could be used. The choke is more desirable because a higher shunting inductance can be obtained for a given maximum al-

lowable d-c resistance in the winding. This is fundamentally because the window area does not have to be shared with a secondary winding. The only disadvantage is that perfect d-c isolation of the yoke cannot be obtained with a choke alone since its resistance is not zero. For example, if a 45 ohm yoke is coupled directly by a 9 ohm choke, then 9/54 of the 200 milliamperes of average collector current, i.e., 33 milliamperes, will flow in the yoke. Permanent magnets can be used to compensate for such an off-centering current, or it can be eliminated by using a blocking condenser in series with the yoke.[4] Since the shunting inductance of the coupling reactor is not infinite, its parabolic current is added to the sweep current to increase the current demand upon the output transistor. This is illustrated in *Fig.* 6 for the case in which the magnetizing inductance is seven times the inductance of the yoke. If the inductance ratio between the choke and the yoke increases, then the effect of the parabolic choke current is proportionally reduced.[4]

Thus the output choke should be designed to have maximum inductance with not more than a certain maximum resistance. This value of resistance will be discussed shortly. In practice, a reasonable core size is chosen, such as that used in current black and white television receivers. The choke is then wound with as many turns as possible without exceeding the maximum resistance value for the winding. Finally, the air gap is adjusted for maximum incremental inductance when the design value of average current is in the coil.

The question of the resistance of the choke, and hence of the maximum inductance attainable with a given core, is closely coupled to the problem of thermal stability in the output circuit. For thermal stabilization an emitter resistance will be inserted as shown in the zero frequency equivalent circuit of the output stage, *Fig.* 7. The resistance in the collector, R_C, represents the choke and yoke in parallel, unless a coupling capacitor is used, in which case R_C is just the choke resistance. To a first order approximation there is no signal current in R_C because of the choke inductance. Since R_E is bypassed, there is none in R_E either. So, effectively the a-c power to the yoke and the transistor must come from the available power from the battery. This is $E^2/4(R_{dc})$. The yoke requires $(1/12)I^2\ R_{yoke}$, where I is the peak-to-peak sweep current, and the transistor requires $(1/6)\ I^2\ R_{yoke}$. This follows since the ideal efficiency of a Class A sweep circuit is 33.3 percent.* The maximum value of resistance, R_{dc}, is figured by equating the maximum available power to that required by the yoke and the transistor. That is,

$$\frac{E^2}{4R_{dc}} = \frac{1}{4}\ I^2\ R_{yoke}$$

*This assumes a purely resistive load which is not exactly the case here. The error involved in these rough power calculations, however, is not excessive for this purpose.

Hence,

$$R_{dc\ (max)} = \frac{(E/I)^2}{R_{yoke}}$$

For a 12-volt battery with I equal to 0.4 amperes and a yoke resistance of 45 ohms,

$$R_{dc\ (max)} = 20 \text{ ohms}$$

This d-c resistance must be divided between the emitter stabilizing resistance and the choke. In order to minimize the parabolic current in the choke, as much as possible of this 20 ohms must be allowed for the choke; as much, that is, as thermal stability considerations and efficiency will allow. Thus, some sort of compromise is indicated between the desired large value of the choke inductance on one hand and a margin of thermal stability and power efficiency on the other. Such a compromise may be facilitated by the following analysis of these factors for the output stage.

IV. Design Of Output Stage

The output stage will be studied with the aid of the circuits shown in *Fig.* 7. The following assumptions are made:

1. The coupling capacitor, C, is sufficiently large[4] so that its effect on operation is negligible. This

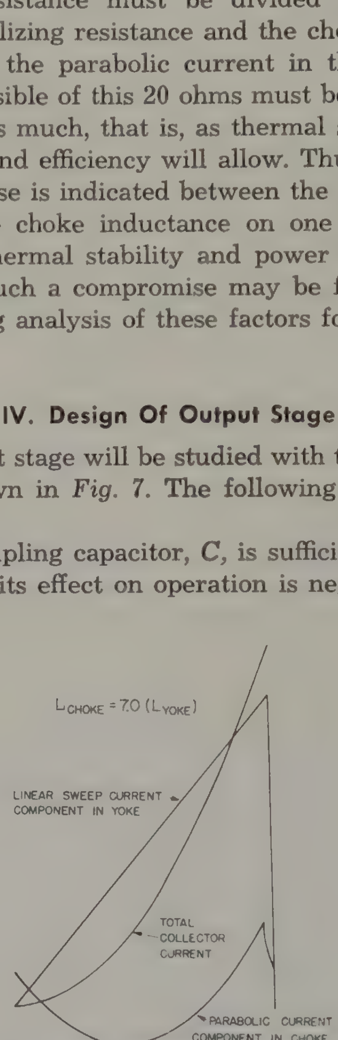
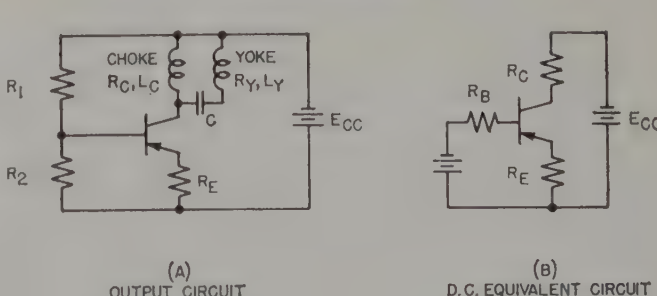


Fig. 6.—Non-linearizing effect of choke current on collector current.



$P_a = E_{CC}^2/4\,(R_E + R_C) = E_{CC}^2/4R_{DC}$

$R_{DC} = R_E + R_C$

$R_B = R_1 \| R_2$

Fig. 7 — Vertical deflection output stage.

is easily achieved in practice.

2. The inductance of the choke greatly exceeds that of the yoke. Thus, the *a-c* component of current in the choke is neglected. In practice this is only a fair approximation. The results obtained using this approximation, however, are useful in determining the starting point of a design and the direction in which to proceed to obtain desired variations in the relevant factors.
3. The emitter to base voltage is much less than the voltage across the emitter resistance. This is needed to facilitate thermal stability calculations. If the emitter resistance is at least two or three ohms this is a fairly good approximation.
4. The current gain of the transistor is nearly constant. For the sweep current presently required, i.e., 400 milliamperes typically, this is not too difficult to achieve with available transistors.
5. The yoke may be modified by changing the wire size but the window area available is constant. Core saturation is not a problem.
6. The choke is wound on a given core size with a fixed window area. Saturation is a problem to the extent that an air gap is necessary, and, in fact, supports almost all of the magneto-motive force.
7. The saturation resistance and cut off current of the transistor are small so that the collector current and voltage each can swing down to zero. This is reasonable for germanium power transistors.
8. The external base resistance, R_B, in *Fig. 7B* is limited to a maximum value by the breakdown characteristics of the collector. That is, the collector can support more voltage with respect to the emitter if the base resistance is lower. It is undesirable to use a lower value than this maximum because of its shunting effect on the signal which effectively reduces the stage gain. In the example given, 200 ohms is used.
9. For the purpose of power considerations the yoke is considered to be a pure resistance. This introduces 10 to 20 percent error in the power calculations, not a negligible amount, but certainly small enough for a first approximation.

Implications of the assumptions will be given at the appropriate points in the analysis.

The first characteristic of the design to be studied is the relation between the total *d-c* resistance and the *a-c* load resistance. In other words, what must the yoke resistance be for values of supply voltage, choke resistance, and emitter resistance? Yoke power requirements and load line considerations lead to the answer. It follows from assumption No. 5 that the yoke window area is constant, that the time constant of the yoke, L_Y/R_Y, is constant.[4]

The ampere turns in the yoke must remain constant and the yoke inductance varies as the square of the number of turns. Hence it follows that the sweep current varies inversely as the square root of the inductance. Therefore, the power dissipated in the yoke during sweep does not vary as the yoke impedance is changed. Let P_o be this power. As illustrated in *Fig. 1*, the power dissipated in the transistor is twice that in the yoke, i.e., $2P_o$. Hence the total power consumption in the yoke and transistor is $3P_0$. The source of this power is the battery and the source impedance is R_{dc}, the sum of the choke and emitter resistors. Thus if a constant power hyperbola for $3P_o$ is plotted on the output voltage-current plane, and the *d-c* load line for E_{cc} and R_{dc} is drawn, then the intersection of these two is the proper bias point for that source voltage and resistance, and yoke dissipation. In *Fig. 8* this is done for the general case and also for a specific case in which $E_{cc} = 12$ volts and $P_o = 0.6$ watts. The *a-c* load line, whose slope is the yoke resistance, R_Y, is tangent to the $3P_o$ power curve at its intersection with *d-c* load line. From these geometrical considerations the following relation can be derived.*

$$R_Y = R_{dc}\left\{\frac{1+\sqrt{1-\dfrac{12\,P_oR_{dc}}{E_{cc}^2}}}{1-\sqrt{1-\dfrac{12\,P_oR_{dc}}{E_{cc}^2}}}\right\}$$

Notice that $E_{cc}^2/4(R_{dc})$ is the maximum power available to the transistor and yoke from the battery and R_{dc}. This means that there is a maximum value that R_{dc} can have and still be able to supply the necessary $3P_o$. This occurs when the *d-c* load line is tangent to the $3P_o$ curve, or when

$$E_{cc}^2/4\,R_{dc} = 3P_o$$

If this available power is called P_a then the above relation becomes

$$R_Y = R_{dc}\left\{\frac{1+\sqrt{1-\dfrac{3P_o}{P_a}}}{1-\sqrt{1-\dfrac{3P_o}{P_a}}}\right\}$$

in which it is evident that the determining factor is the ratio of required power, $3P_o$, to the available power P_a. This relation is plotted in *Fig. 9* for the general case in terms of $3P_o/P_a$ and for our specific example in terms of R_{dc}.

Although the value of yoke impedance is necessary for the circuit design it is not an important factor in itself. More important is the input power which must be supplied by the battery. Since the power consumed in the yoke and transistor is fixed, the input power will be increased only by the power dissipated in the emitter and choke resistance. This power has been derived** and is given by

$$\frac{P_{in}}{3P_o} = 2\sqrt{\frac{P_a}{3P_o}\,\frac{1-\sqrt{1-3P_o/P_a}}{1+\sqrt{1-3P_o/P_a}}}$$

---

*Appendix A
**Appendix B

where, again, the determining factor is the ratio of required to available power. This relation for the general and specific cases is plotted in *Fig. 10*. These curves show one of the factors involved in the compromise, i.e., power input. The next factor to be examined is thermal stability.

One of the important quantities involved in calculating thermal stability[5] is the quiescent collector voltage. As far as this factor alone is concerned, it is desirable to increase R_{dc} as much as possible since this reduces the quiescent collector voltage, E. This is evident from *Fig. 8*. The exact relation is $E/E_{cc} = 3P_o/P_{in}$, which follows from $E = 3P_o/I_{av}$ and $E_{cc} = P_{in}/I_{av}$. Hence the curve at the left of *Fig. 10* gives the reciprocal of the quiescent voltage reduction.

In addition to E, there are three other quantities that must be controlled or accounted for to prevent thermal runaway. First is the thermal resistance, K, between the transistor junction and the ambient, which is a constant in this design. The leakage current at the junction temperature which would be reached if there were no leakage current is a second factor. This temperature is T_1 and the corresponding leakage I_{co}/T_1. Since the ambient temperature, the thermal resistance, K, and the collector dissipation in the absence of I_{co}, $(3P_o)$*, are all constants, this leakage current factor is also constant. That is

$$T_1 = T_a + K\,(3P_o)$$

is constant when T_a, K and P_o are fixed, hence I_{co}/T_1, is fixed for a given transistor. The third factor is the variation of collector current with leakage current, S. This is the familiar stability factor defined by Shea.[3] For the circuit of *Fig. 7B* this is

$$S = \frac{1}{1 - \alpha\,\dfrac{R_B}{R_E + R_B}}$$

Since in this analysis α and R_B have been fixed, the only parameter that affects S is R_E. The variation of S with R_E for the example at hand is shown in *Fig. 11*.

Thermal runaway will be impossible if the product of S, K, E, and I_{co}/T_1 is less than 5.3 K and I_{co}/T_1 are constants and the behavior of S and E has been considered. In order to combine these factors, realistic values will be chosen for the constants. Let the thermal resistance be $K = 5.55$ °C/W, and the room temperature (25 degrees C) leakage current be 0.2 *ma*. The maximum ambient in which this circuit must operate is 45 degrees C. Thus,

$$\begin{aligned} T_1 &= T_a + K\,(3P_o) \\ &= 45°\text{C} + (5.55°\text{C/W})\,(1.8 \text{ watts}) \\ &= 55°\text{C} \end{aligned}$$

and

*Although the power in the transistor is $2P_o$ during a full scan the factor $3P_o$ is used because it allows for higher dissipation when the signal is absent.

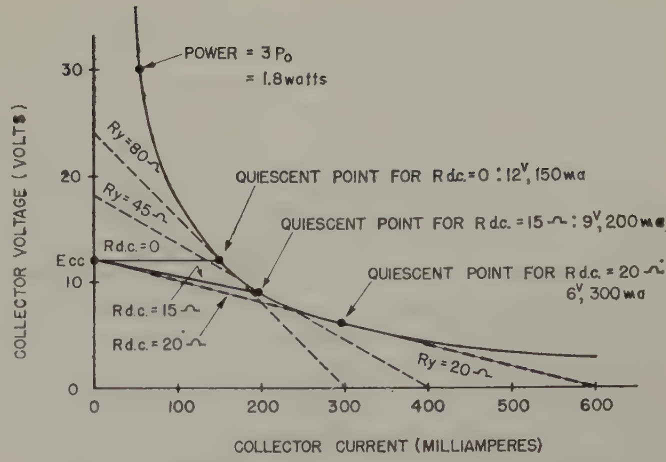


Fig. 8 — Output plane: *a-c* and *d-c* load lines.

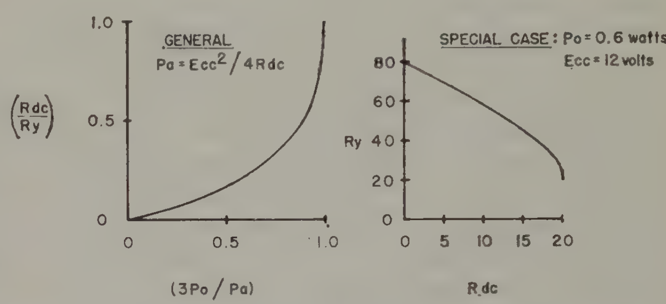


Fig. 9 — Yoke resistance vs. emitter plus choke resistance.

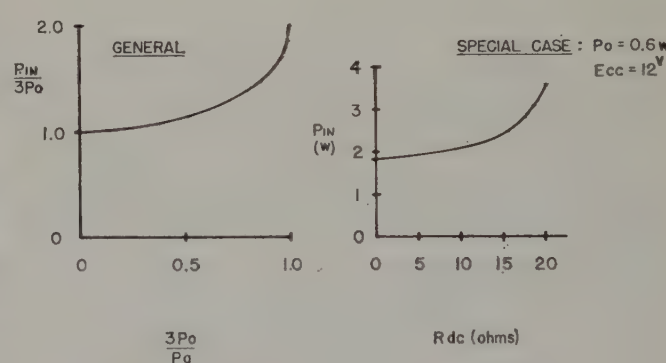


Fig. 10 — Power input vs. *d-c* resistance.

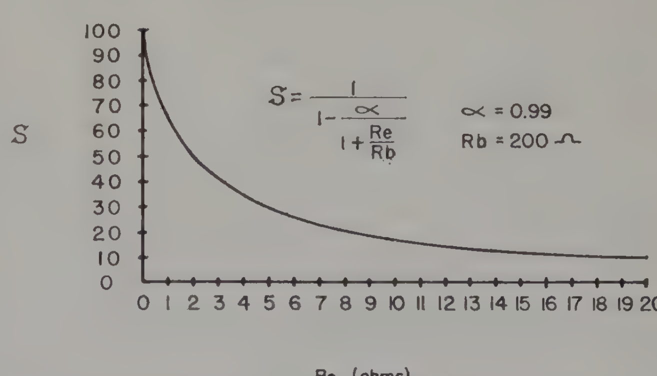


Fig. 11 — Variation of stability factor with emitter resistance.

$$I_{co}/T_1 = 0.2\ ma \times 2\left(\frac{55\text{-}25}{10}\right)$$
$$= 1.6\ ma$$

Thus, for every pair of values of R_{dc} and R_E the product $SKEI_{co}/T_1$ can be found. These values have been plotted in *Fig. 12,* from which it is evident that for a two to one stability margin the total *d-c* resistance should exceed 5 ohms. Also, the emitter resistance can never be less than 2 ohms. These curves have not been plotted for values of R_E less than 2 ohms because the approximation (#3) regarding negligible emitter-base voltage would become unjustifiable. Furthermore, the value of R_E cannot equal the value of R_{dc}, since this would imply a zero resistance choke.

At this point, with the aid of *Figs. 10* and *12,* values may be selected for R_{dc} and R_E on the basis of power input and thermal stability considerations. For example, if 2.5 watts input power cannot be exceeded, then R_{dc} must be less than 16 ohms. With a 2:1 thermal stability margin, R_E must exceed 4 ohms. However, one further quantity must be considered in the final choice. The inductance of the choke must greatly exceed that of the yoke. This has been assumed throughout and an attempt must be made to insure this condition.

It follows from assumption No. 6*, that the core is fixed and that an air gap is required to prevent saturation, that the inductance of the choke is proportional to the square root of its resistance and to the square root of the yoke resistance. That is

$$L_c = L_c^0\sqrt{\frac{R_c}{R_c^0}}\sqrt{\frac{R_y}{R_y^0}}$$

in which the subscripts c and y refer to the choke and yoke respectively and the superscript "0" refers to a prototype value for that parameter. The yoke inductance on the other hand is proportional to the yoke resistance

$$L_y = L_y^0\left(\frac{R_y}{R_y^0}\right)$$

because the time constant remains constant for a given window area and with a fixed magnetic path. The ratio of choke to yoke inductances is therefore

*See Appendix C

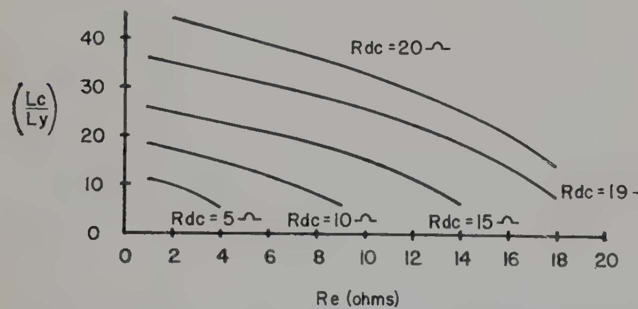


Fig. 13 — Choke to Yoke inducantce ratio versus R_{dc} and R_e.

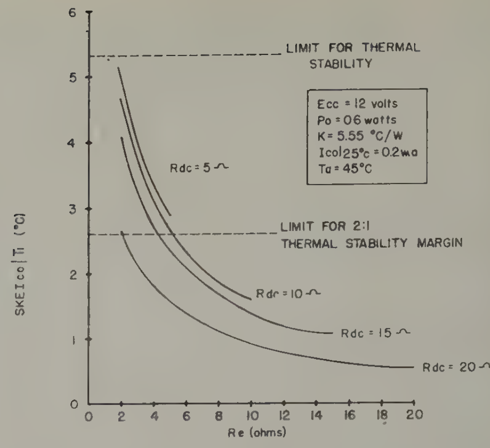


Fig. 12 — Thermal stability versus R_{dc} and R_e.

$$\frac{L_c}{L_y} = \frac{L_c^0}{L_y^0}\frac{\sqrt{R_c/R_c^0}}{\sqrt{R_y/R_y^0}}$$
$$= \left(\frac{L_c^0}{L_y^0}\sqrt{\frac{R_y^0}{R_c^0}}\right)\left(\sqrt{\frac{R_c}{R_y}}\right)$$

The first bracket in this expression is a constant for given yoke and choke prototypes. The second bracket describes the variation from this prototype. In the practical case under analysis prototype values are:

$$L_y^0 = 45\ mhy.,\quad R_y^0 = 45 \text{ ohms}$$
$$L_c^0 = 1\ hy.,\quad R_c^0 = 10 \text{ ohms}$$

Substituting these values the inductance ratio becomes,

$$\frac{L_c}{L_y} = 47.1\sqrt{\frac{R_c}{R_y}}$$

To relate this to our previous work, the yoke resistance is identified as R_{ac} and the choke resistance as $R_{dc} - R_E$. Thus,

$$\frac{L_c}{L_y} = 47.1\sqrt{\frac{R_{dc}-R_E}{R_{ac}}}$$

The relation between R_{dc} and R_{ac} has been given in *Fig. 9,* hence the inductance ratio may be plotted as a function of R_{dc} and R_E. *Fig. 13* shows this. As a guide to what ratio is needed, the peak-to-peak current in the choke is in the same ratio to the yoke peak-to-peak current, as two and one-half times the ratio of yoke to choke inductances, [4] in a television vertical deflection system. That is,

$$\frac{I_{c\,(p-p)}}{I_{y\,(p-p)}} = \frac{2.5}{L_c/L_y}$$

Thus, if the choke current is to be 1/10 the yoke current swing, then L_c/L_y must be 25. If this requirement is combined with those that led to the minimum value of R_E being 4 ohms and the maximum R_{dc} being 16

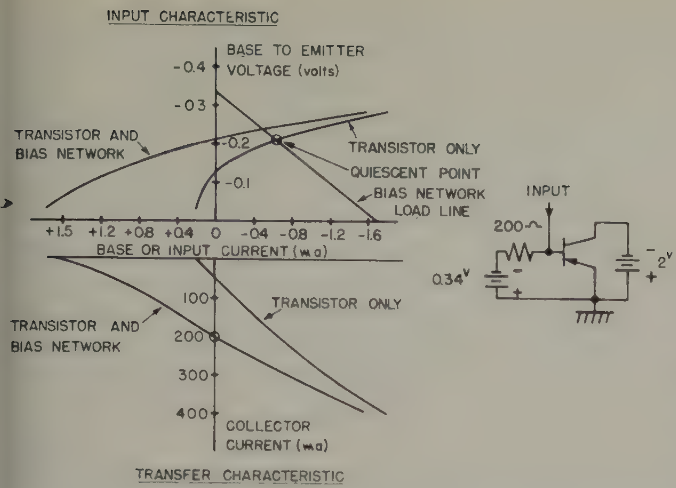


Fig. 14 — Effect of bias network on input and transfer characteristics.

ohms, then from *Fig. 13* it is evident that R_{dc} should also not be much less than 16 ohms and R_E not much more than 4 ohms. Therefore, by means of power input, thermal stability and choke inductance considerations, the values of R_{dc} and R_E have been determined. From these the yoke and choke designs follow immediately. With $R_E = 4$ ohms and $R_{dc} = 16$ ohms, $R_c = 12$ ohms and $R_{ac} = R_y = 42$ ohms (from *Fig. 9*). Since the resistance of the choke is proportional to the square of the number of turns*, the choke prototype has to have its number of turns increased by $\sqrt{12/10} = 1.094$ (and of course its wire cross section decreased by 1/1.094). Similarly the yoke prototype must have its turns decreased by $\sqrt{42/45} = 0.966$ (and its wire size increased by 1/0.966.

With the emitter resistance of the output stage bypassed, the input impedance at signal frequencies is quite low so that the shunting effect of R_B is not too serious. In fact, there is some linearization of the current gain fall-off as emitter current increases. This occurs because accompanying the emitter current increase is a decrease of the input impedance, which decreases the reduction in gain due to the shunting effect of R_B. *Fig. 14* illustrates this effect for a Bendix 2N418, one of several types used as output transistors. For the transistor illustrated, the average current gain over the collector current range of 50 to 350 *ma* is 300/1.45 or 207. When the bias network is included, the average effective current gain becomes $300/2.2 = 136$, a reduction of 33 percent. In practice these current gain values probably would represent the high end of a spread. The design should provide for gain reductions of at least another 50 percent. Thus the input to the output stage must be from 3.2 *ma* to 6.4 *ma* peak-to-peak for a full 400 *ma* sweep in the collector of the output stage characterized by *Fig. 14*. To obtain the waveshape of the drive current it is necessary to combine the required collector current waveform, which depends on the choke to yoke inductance ratio, with the transfer characteristic. *Figs. 6* and *14* are used to obtain the drive waveform of *Fig. 15*.

V. Driver Stage

The drive current may be obtained from either a *p-n-p* or an *n-p-n* driver stage connected in the common emitter or common collector configuration. The common emitter has been chosen because in addition to its high power gain it has a high output impedance. This prevents a voltage developed across an interstage coupling capacitor from affecting the current waveform. An *n-p-n* type was used mostly because it offered the possibility of direct coupling to the *R-C* drive circuit and to the output stage, although *a-c* coupling was later found desirable. It is believed that with minor circuit changes a *p-n-p* common emitter driver would perform as well. The design of the driver stage is relatively simple. The base to emitter waveform necessary to produce a current waveform with the shape shown in *Fig. 15*, but of about twice that amplitude, is graphically determined in *Fig. 16*. The transfer characteristic is that for a Sylvania 2N214, one of the types used as a driver. It is biased at 3 milliamperes. Note that the curvature of the driver's transfer characteristic tends to linearize the required input waveform. The exact shape of the drive waveform depends critically upon the various characteristics of the output and driver transistors pictured in *Figs. 14, 15,* and *16*. Even for given transistors these will vary with bias levels. Variations in choke to yoke inductance ratio will also be significant. Rather than attempting to design a shaping system to accommodate all of these variables, it was decided to use negative feedback around as many of the non-linearities as possible.

Since the voltage swing that appears between the base and emitter of the driver is on the order 60 to 100 millivolts, it is possible to apply considerable voltage feedback and still not require that too large a sweep voltage be generated at the sweep capacitor.

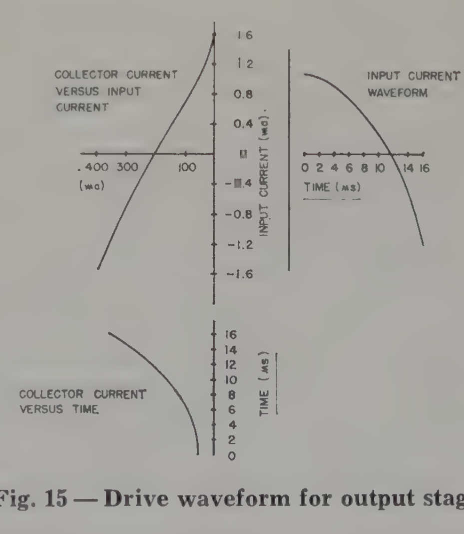


Fig. 15 — Drive waveform for output stage.

*Appendix C

Negative Feedback

This is accomplished by feeding back to the emitter of the driver stage a voltage that is proportional to the yoke current. In *Fig. 17* the resistor R_e samples the yoke current and develops the feedback voltage. A typical value of R_e is 3.3 ohms which, as a result of a 400 milliampere yoke current sweep, will feed back 1.32 volts of sweep to the emitter. The feedback is therefore on the order of 25 *db*. Feedback of this type requires additional power from the output stage. With a yoke resistance of 45 ohms and a 3.3 ohm feedback resistor, the increase amounts to 6.8 percent. The design of the power stage consequently should include the feedback resistor as part of the yoke resistance.

In addition to the negative feedback, the circuit of *Fig. 17* differs from the simple circuit of *Fig. 5* by the use of a-c coupling. The sweep capacitor is coupled to driver stage by means of C_1 and the driver to the output by C_2. The first of these capacitors was found necessary to prevent a stable lockout of the first stage which occurred if the system did not regenerate upon closing of the diode. In this condition the driver stage is on hard and its collector is saturated, reducing loop gain to near zero. The second capacitor, C_2, was added to provide independent choice of the driver operating point for best linearity. It might be possible to eliminate this latter capacitor by stabilizing the combined transistor pair.

Shaping

Negative feedback does not reduce the nonlinearity inherent in the *R-C* charge circuit. For this reason, and to further reduce the over-all distortion, some shaping of the waveform applied to the base of the driver is provided by using positive feedback. As shown in the simplified circuit of *Fig. 18*, the output sawtooth is integrated by means of the sweep resistance and capacitance to provide a parabolic component of voltage across the sweep capacitor C_{sw}. This is added to the linear term due to the average potential at the lower end of the sweep resistance, R_{sw}, which is set by the divider $R_1 - R_2$. Actually the waveform is exponential in character, the parabolic approximation being valid only over a time interval less than the circuit time constant. This is easily satisfied in practice. The relative amounts of parabola and ramp can be adjusted by varying the turns ratio of the positive feedback winding and the *d-c* level set by the divider.

Driver Design Details

The driver stage, since it has considerable *d-c* resitance in its collector circuit, does not pose a difficult problem with regard to thermal stabilization. That is, it cannot run away. However, there will be a change in collector current, and hence voltage, as the transistor heats up and the design must insure sufficient voltage aperture at all operating temperatures and values of battery voltage.

The effective bias circuit and design equations are shown in *Fig. 19*. The quiescent collector current is chosen large enough to handle the required collector current swing and not so large that it forces operation in the region where current gain has fallen off appreciably. For this design and for the types of transistors considered, i.e., T.I. 2N366 and Sylvania 2N214, a value of 4 milliamperes is chosen. Thermal resistance, *K*, is 250°C/W and room temperature leakage current is 10 microamperes.

At low values of quiescent collector voltage the stability factor is seen from the relation

$$S_I = \frac{V_c}{E}(\beta - 1) + 1$$

to be very good. However, the collector resistance is larger when V_c is smaller. The first of these results leads to a small change in collector current with temperature and the second means that the effect on collector voltage is increased. Thus we have opposing factors and the extent must be qualitatively determined in order to select the proper quiescent collector voltage. Since we are interested in the change in collector voltage, we can use the relation

$$\Delta V_c \approx S_I R_c I_{co}/T_1$$

Actually $R_B \,||\, R_c$ should be used in place of R_c, but the error is small. The temperature T_1 is given by

$$T_1 = T_a + KV_cI_c$$

where T_a = ambient temperature = 50°C
K = thermal resistance = 250°C/W

From the relations in *Fig. 19*, the product S_IR_c has been plotted in *Fig. 20A* as a function of the collector voltage. I_{co}/T_1 is calculated and included in *Fig. 20B*

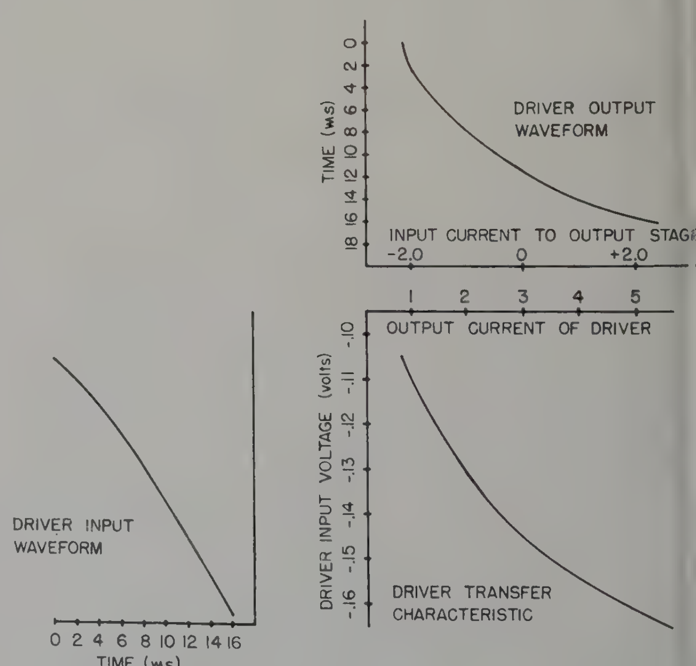


Fig. 16 — Driver input waveform.

to give the shift in collector voltage. Finally, by subtracting the shift from the "cold" quiescent voltage, that is, the collector voltage when the junction is at room temperature, the minimum collector aperture is obtained. This is shown in *Fig. 20C*. The method used thus far assumes that the junction equilibrium temperature will be near T_1, a fair assumption.

From *Fig. 20C* it is seen that if at least 3 volts of aperture is necessary, then the cold quiescent collector voltage must be at least one-half of the battery voltage. Therefore, $V_c \geq 6$ volts. Three volts aperture is sufficient to handle the collector and emitter voltage swings plus a volt decrease in the battery supply voltage.

It is desirable not to go much above 6 volts for two reasons. First, the value of R_c is decreasing and loss of signal gain will be suffered when R_c approaches the input resistance of the driver. Second, the equilibrium junction temperature will be higher as V_c approaches the battery voltage. The calculation of the equilibrium temperatures for the various designs involves considerable familiarity with the material on Transistor Thermal Stability[5] and some extensions of that work. It will not be presented here. The results are such that with a 50°C ambient this stage will stabilize at a junction temperature below 85°C if the collector-to-battery voltage ratio is less than 0.8. Hence, from this and the curve in *Fig. 20C* the design should be for

$$0.5 < (V_c/E) < 0.8$$

A value of 0.6 is chosen with a corresponding collector resistance of $R_c = 1.2$ kilohms and a base resistance, R_B of about 90 kilohms.

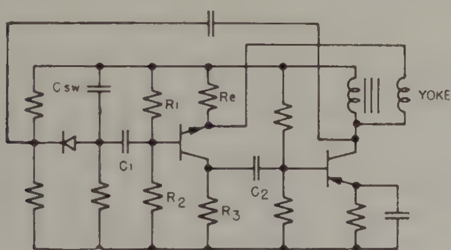


Fig. 17 — Vertical deflection circuit with negative feedback and *a-c* coupling.

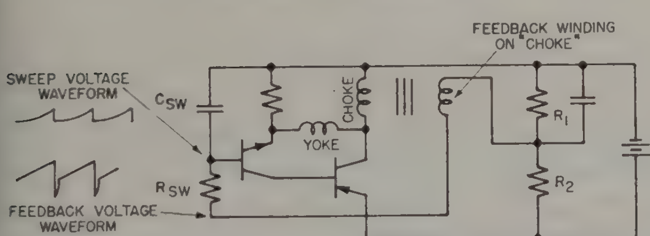
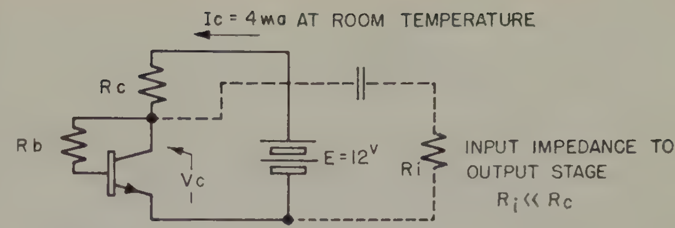


Fig. 18 — Simplified schematic showing positive feedback shaping during sweep time.



APPROXIMATE QUIESCENT DESIGN EQUATIONS:

$$R_b = \frac{V_c}{I_c}\beta \qquad R_c = \frac{E}{I_c}\left(1 - \frac{V_c}{E}\right)$$

$$S_I = \frac{V_c}{E}(\beta - 1) + 1$$

Fig. 19 — Driver circuit and design equations.

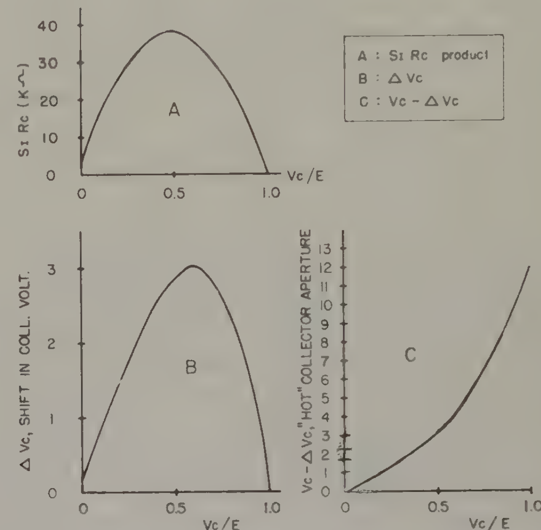


Fig. 20 — Maximum variation in collector voltage and aperture.

VI. Final Circuit

The results of the development described in the preceding sections are shown in *Fig. 21*. The choke, *L*, and capacitor, C_1, form an *LC* filter to keep noise from other sections of a TV receiver out of the vertical. The positive feedback winding connected to the sweep resistor, R_5, is returned to an adjustable *d-c* level through potentiometer R_2 which serves as a linearity control by proportioning the amount of linear ramp to parabola developed at the sweep capacitor, C_2. Potentiometer, R_5, is used to control the charging time constant and hence the frequency of oscillation. R_2 and R_5 interact, hence they must be simultaneously adjusted. Resistor R_6 in series with the sweep capacitor, C_2, increases the high frequency closed loop gain improving the retrace operation and ease of triggering. Condensers C_4 and C_7 are coupling capacitors. R_7 serves to steer the negative sync pulse to the base of the driver where it is amplified and then, via the output stage and feedback network (C_3, R_4, R_3), returns to the left side of the crystal diode to close the loop. R_4 controls the amount that the sweep capacitor is discharged during retrace time, and in this way controls sweep amplitude. C_6 is a blocking condenser to keep any off-centering average current

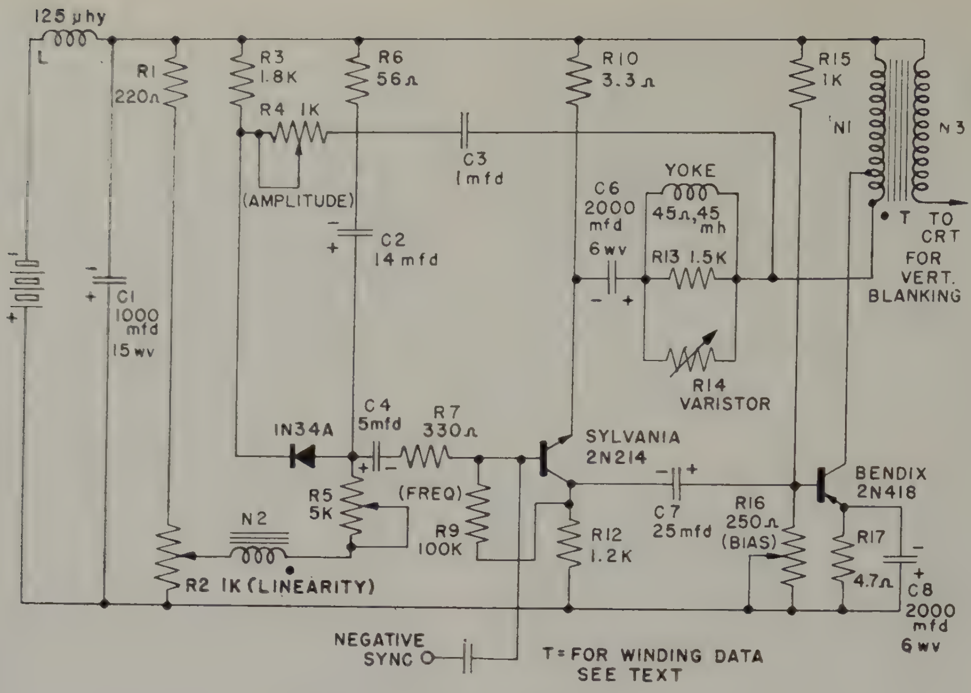


Fig. 21 — Complete schematic.

out of the yoke. The varistor across the yoke clamps the flyback pulse preventing damage to the output transistor. During the sweep period, when its resistance is higher, it presents a minimum of extra load on the output stage. R_{13} is a damping resistance also. R_{15} and R_{16} form an adjustable bias divider to accommodate different output transistors. The transformer is wound on a 7/8-inch core of the type used in the vertical output transformer of black and white receivers. N_1 has 840 turns of #24 SF tapped at 280 turns. The feedback winding, N_2, is 280 turns of #36 SF, and the vertical blanking winding, N_3, is 2500 turns of #40. The resistance of the primary is 8 ohms. A 6 mil air gap is used and the measured primary inductance is 0.93 *hy* with 250 *ma* d-c in the winding.

Performance

Circuits, triggered with negative sync as shown, have pulled in from 10 c.p.s. Positive sync applied to the base of the output stage has not been as effective, pulling in from 48 c.p.s. The problem of using positive sync has not been explored to any great extent. One possible alternative is to use a *p-n-p* driver stage driven from a positive going voltage. A positive pulse at the base of this driver might produce results similar to those obtained in the present circuit.

Up to 400 milliamperes of acceptably linear sweep has been obtained with a supply of 12 volts at about one-fourth ampere.

Acknowledgment

The contributions of Mr. C. H. Wood, Jr., are acknowledged, particularly in connection with experimental work and the negative feedback.

Appendix A

Relation Between A-C and D-C Load Resistance in Output Stage

In Fig. 8, which shows the d-c and a-c load lines for the output stage,

P_o = power dissipated in yoke

R_y = *a-c* resistance (yoke resistance)

R_{dc} = total *d-c* resistance, i.e., $R_C + R_E$ of *Fig. 7*

Since the transistor and the yoke dissipate $3P_o$, the quiescent point must be on the corresponding hyperbola, therefore

$$E \times I_{av} = 3P_o \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where E is the quiescent collector to emitter voltage and I_{av} is the quiescent collector current. Then with E_{cc} the battery voltage

$$E = E_{cc} - I_{av} \cdot R_{dc} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Combining (1) and (2):

$$3P_o = (E_{cc} - I_{av} R_{dc}) I_{av}$$

or

$$I_{av} = \frac{1}{2}\frac{E_{cc}}{R_{dc}} - \sqrt{\frac{1}{4}\frac{E_{cc}^2}{R_{dc}^2} - \frac{3P_o}{R_{dc}}} \quad . \quad . \quad . \quad (3)$$

The *a-c* load line will have a slope

$$R_y = \frac{E_{cc} - I_{av} R_{dc}}{I_{av}} = \frac{E_{cc}}{I_{av}} - R_{dc} \quad . \quad . \quad . \quad (4)$$

Combining (3) and (4) yields:

$$R_y = R_{dc}\left\{\frac{1 + \sqrt{1 - \frac{12 P_o R_{dc}}{E_{cc}^2}}}{1 - \sqrt{1 - \frac{12 P_o R_{dc}}{E_{cc}^2}}}\right\} \quad . \quad . \quad . \quad (5)$$

Appendix B

Input Power

The power dissipated in the yoke at full scan is

$$P_o = \frac{1}{3} I_{av}^2 R_y$$

The power supplied by the battery is

$$P_{in} = E_{cc} I_{av}$$

Combining these,

$$P_{in} = E_{cc} \sqrt{\frac{3P_o}{R_y}}$$

Using the relation between R_y and R_{dc} derived in Appendix A,

$$P_{in} = \sqrt{\frac{E_{cc}^2 3P_o}{R_{dc}} \left\{ \frac{1 - \sqrt{1 - \frac{12 P_o R_{dc}}{E_{cc}^2}}}{1 + \sqrt{1 - \frac{12 P_o R_{dc}}{E_{cc}^2}}} \right\}}$$

and, finally, inserting $P_a = E_{cc}^2/4 R_{dc}$

$$\frac{P_{in}}{3P_o} = 2\sqrt{\frac{P_a}{3P_o} \cdot \frac{1 - \sqrt{1 - 3P_o/P_a}}{1 + \sqrt{1 - 3P_o/P_a}}}$$

Appendix C

Dependence of Choke Inductance on Choke and Yoke Resistance

In order to avoid saturation, a fixed maximum flux ϕ is chosen. Then the choke inductance will be proportional to the number of turns divided by the average current. Static rather than incremental values of flux and current are used on the assumption that enough air gap must be used to linearize the reactor, that is, the incremental and static permeabilities are nearly equal. Thus

$$L_c \propto \frac{N_c}{I_{av}}$$

where L_c and N_c are choke inductance and turns respectively. Since the power into the yoke is constant in this invariant time constant design

$$I_{av}^2 \propto \frac{1}{R_y}$$

From the assumption of constant choke window area it follows that

$$R_c \propto N_c^2$$

Hence

$$L_c \propto \sqrt{R_c R_y}$$

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Transition Capacitance Of P-N Junctions*

R. L. PRITCHARD**

The capacitance-voltage relation is calculated theoretically for three types of one-dimensional impurity distributions which are intermediate between that of an abrupt and a uniformly graded junction. These theoretical distributions, which approximate the type of impurity distribution obtained in a grown or diffused junction, are termed the hyperbolic, exponential, and graded-abrupt. For small values of applied voltage, each distribution resembles a uniformly graded junction, in which the capacitance is inversely proportional to the cube root of voltage, whereas for larger voltages, the space-charge layer extends almost entirely into the uniform conductivity region, and the capacitance becomes proportional to the square root of voltage. In the intermediate range of voltages, however, it turns out that for each of the three distributions studied, the capacitance remains very nearly proportional to the cube root of voltage, even when the latter is such that the space-charge-layer extends well into the non-uniformly graded portion of the distribution. As a result, it is emphasized that if a cube-root voltage relation is measured for a *p-n* junction, it *cannot* be assumed that the junction is simply uniformly graded. Also included are calculations of the space-charge-layer widening factor, which is important for characterizing certain electrical parameters of a transistor.

[Tear sheets of this article are available on written request]

THE CAPACITANCE associated with the transition region of a *p-n* junction is a function of the voltage applied to the junction (including the internal contact potential). For abrupt, or step, type junctions the capacitance varies inversely as the square root of the voltage, whereas for a uniformly graded junction, the capacitance is inversely proportional to the *cube* root of the voltage.[1]

These relations have been verified experimentally for many types of p-n junctions in both germanium and silicon, e.g., an alloy, or fused, junction generally behaves somewhat like an abrupt junction,[2] [3]

*The material described here was originally prepared at the General Electric Research Laboratory in 1956, and was included in a paper "Small-Signal Parameters of Junction Transistors Having Non-Uniform Base Resistivity," presented at the AIEE-IRE Semiconductor Devices Research Conference at Purdue University, Lafayette, Indiana, 25 June 1956. It has been brought up to date in this presentation.

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whereas most grown junctions generally are considered to be of the uniformly graded type.[4]

However, if an inverse-cube-root capacitance-voltage relation is observed experimentally for a p-n junction, it is *not necessarily true* that the junction is uniformly graded. Results of theoretical calculations described below indicate that the capacitance-voltage relation is *not* a very sensitive measure of the impurity distribution through the p-n junction. In particular, the impurity distribution may depart quite significantly, (e.g., several hundred percent) from the uniformly-graded type before the capacitance-voltage relation departs appreciably (e.g., 5-10 percent) from the cube-root relation.

Calculations are carried out for impurity distributions between semiconductor regions of opposite conductivity type, such as might occur in *grown* or *diffused* junctions. The type of impurity distribution that exists in an alloy or metal-semiconductor junction to a semiconductor wafer, i.e., an abrupt transition between a region of very high conductivity and a region of lower conductivity and opposite type, has been discussed by Giacoletto[6], and will not be considered here.

Capacitance-Voltage Relation

In the classical calculation for the capacitance-voltage relation, Poisson's equation in one-dimension is solved for a voltage-distance relation corresponding to a fixed spatial distribution of impurity charge-density.[5] [6] Such a calculation neglects the concentration of free electrons and holes in the depletion-layer region. In most practical cases, this is a good approximation.[1] [6] The limits of the junction are defined as the two points at which the electric field is zero. Then, the distance x_m between these two points is related to the voltage difference between the points, and capacitance is calculated from the classical equation:

$$C = \frac{S\,\epsilon_0\,\epsilon_r}{x_m} \qquad (1)$$

with x_m as a function of junction voltage. In this equation S is the cross-section area of the junction, ε_0 is the premittivity of free space, and ε_r is the relative dielectric constant of the semiconductor material. The distance x_m generally is termed the depletion-layer width.

In practical structures which include regions of uniform impurity concentration, i.e., of uniform conductivity, a p-n transition is likely to be intermediate between the abrupt and uniformly graded type. The latter two types are shown in *Figs. 1a* and *1b*, respectively, while the intermediate transition is shown in *Fig. 1c*. For small depletion-layer width, (small applied voltage) the depletion layer lies in a region of linearly varying concentration, as shown by the shaded region in *Fig. 1c*, and the junction behaves like a uniformly graded junction. However, as the

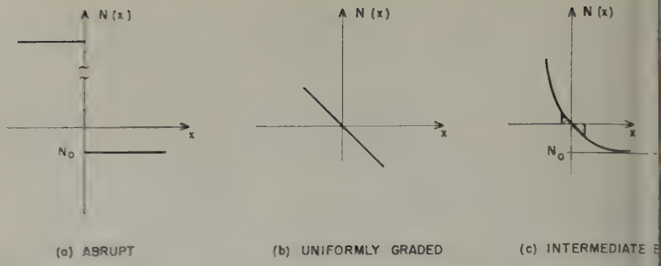

Fig. 1—Impurity distributions for different types of p-n transitions. (a) Abrupt, or step, (b) Uniformly graded (c) Intermediate, with uniform concentration on one side.

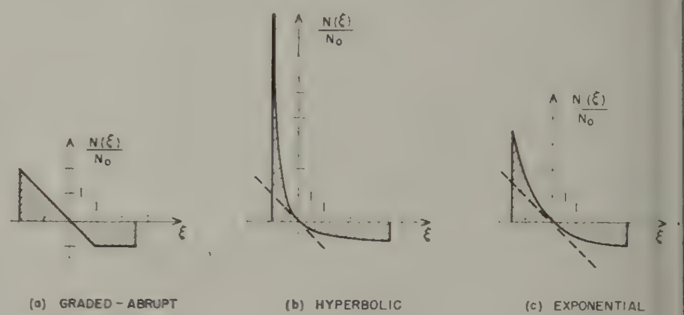

Fig. 2—Impurity distributions for three types of intermediate p-n transistions in terms of normalized coordinate system. (a) Graded-abrupt (b) Hyperbolic (c) Exponential.

width of the depletion layer is increased, by increasing applied voltage, proportionately more of the layer must move into the region of constant concentration in order that the total charge be equal on each side of the transition region. Ultimately, the depletion layer is confined almost completely to the constant-concentration side of the junction, i.e., the right side of *Fig. 1*, and the junction behaves like an abrupt junction.

Non-Uniformly Graded Impurity Distribution

Three types of intermediate impurity distribution were analyzed, each of which is characterized by a variable concentration on one side and a limiting constant concentration on the other.[7] These distributions are shown in *Fig. 2* and are defined mathematically below. To facilitate comparison, a normalized coordinate system is employed in which the ordinate is N/N_0, and the abscissa is $\xi \equiv x/x_0$, where N_0 is the value of the uniform concentration, and x_0 is a characteristic distance, e.g., the point at which the graded junction changes to abrupt in *Fig. 2a*.

The types are:

(a) Graded abrupt (*Fig. 2a*), $N(\xi)/N_0 = \begin{cases} -\xi;\ \xi \le 1 \\ -1;\ \xi \ge 1 \end{cases}$ (1)

(b) Hyperbolic (*Fig. 2b*), $N(\xi)/N_0 = \dfrac{-\xi}{1+\xi}$ (2)

(c) Exponential (*Fig. 2c*), $N(\xi)/N_0 = (\epsilon^{-\xi} - 1)$ (3)

Note that in each of the three cases, for small values of normalized distance ($\xi \ll 1$), the impurity distribution $N(x)$ is essentially equal to $-(N_0x/x_0)$, which corresponds to a uniform impurity gradient of $-(N_0/x_0)$. On the other hand, for large values of ξ, the impurity distribution in each case approaches $-N_0$.

Appropriate solutions to Poisson's equation for each of these three cases are given in the Appendix. Although the results are quite simple in form, unfortunately in each case the applied voltage is related *implicitly* to the depletion-layer width, and a simple capacitance-voltage relation does not exist, as in the case of a uniformly graded, or abrupt, junction. However, numerical calculations can be carried out very easily, and the results can be displayed graphically, as shown by the curves in *Figs. 3, 4*, and *5*. In these curves the normalized depletion layer width ξ_m is presented as a function of normalized voltage V_c/V_0, where the normalizing voltage is defined as

$$V_0 \equiv (N_0 x_0^2\, q_e/\epsilon_0\, \epsilon_r), \tag{4}$$

and where q_e is the electronic charge (1.6×10^{-19} cb.). In each case, the upper dashed curve indicates the corresponding relation for the uniformly graded junction having the same gradient of $-(N_0/x_0)$.

Also shown in each figure are the normalized distances ξ_1 and ξ_2, defined as the relative penetration of the depletion layer into the uniform-concentration and variable-concentration sides of the junction respectively, together with the dotted curve representing $\xi_1 = \xi_2$ for the corresponding uniformly graded junction. For small values of normalized voltage, (V_c/V_0), ξ_1 and ξ_2 are each equal to half the normalized depletion-layer width ξ_m, but as the voltage is increased and the depletion-layer penetrates more deeply into the uniform-concentration side of the junction, ξ_1 becomes increasingly larger than ξ_2. Note, however, that the relation between junction voltage V_c and depletion-layer width ξ_m remains essentially the same as in a corresponding uniformly graded-junction, even though the junction has become considerably unsymmetrical as indicated by the difference between ξ_1 and ξ_2. It should be emphasized that in applying these curves to practical cases, the voltage V_c refers to the *total* junction voltage, which is equal to applied voltage plus the internal contact potential (generally of the order of a few tenths of a volt, e.g., 0.3 — 0.5 volts for germanium). [1] [6] [7]

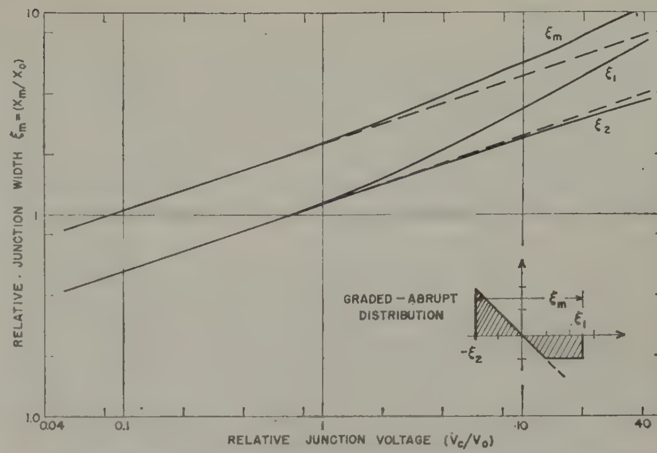

Fig. 3—Relative junction width (inversely proportional to junction capacitance per unit area) as a function of relative junction voltage for graded-abrupt distribution, showing relative penetration into each side of junction.

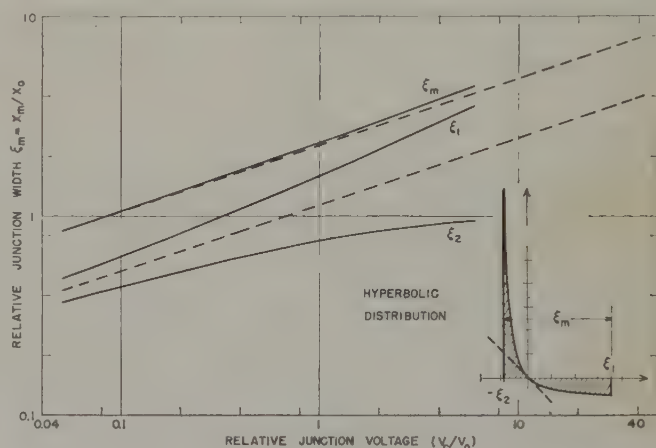

Fig. 4—Relative junction width (inversely proportional to junction capacitance per unit area) as a function of relative junction voltage for hyperbolic distribution, showing relative penetration into each side of junction.

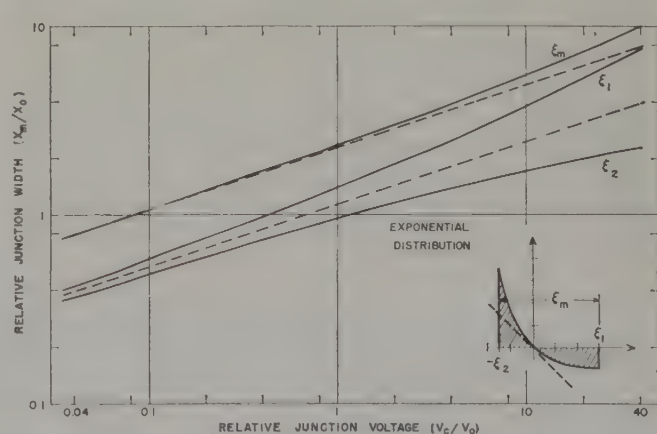

Fig. 5—Relative junction width (inversely proportional to junction capacitance per unit area) as a function of relative junction voltage for exponential distribution, showing relative penetration into each side of junction.

Example

The theory presented above may be illustrated by referring to the exponential distribution of type (c) above. This particular distribution is a reasonably good approximation for the impurity distribution through a p-n junction that has been fabricated by the solid-state diffusion technique.[8] For example, consider a junction formed by diffusing an impurity having a surface concentration of 10^{18} atoms/cm^3 into a semiconductor wafer with an initial impurity concentration of 3×10^{15} atoms/cm^3 (e.g., 2 ohm-cm n-type silicon). If the diffusion length for the impurity in the wafer is 1.5×10^{-4} cm, then the p-n

transition will occur at a distance of 6.3×10^{-4} cm from the surface.

Although the impurity distribution between the surface and the *p-n* transition is described mathematically by an error function, in the vicinity of the *p-n* transition, the error function can be approximated fairly well by an exponential function, such that

$$N(x) \doteq 3 \times 10^{15}\ \{\epsilon^{-1.5 \times 10^4 x} - 1\},\ x > -1.5 \times 10^4 \text{ cm}$$

where x is measured in cm from the center of the *p-n* transition. Hence, the constants N_0 and x_0 in Eq. (3) above are 3×10^{15} cm^{-3} and 0.67×10^{-4} cm, respectively, and from Eq. (4) with $\varepsilon_r = 12$ for silicon, $V_0 = 2$ volts. Then *Fig. 5* can be used to evaluate the boundaries of the *p-n* junction as a function of applied voltage V_c. For example, for an applied voltage of 50v, $(V_c/V_0) = 25$, and *Fig. 5* indicates that $\xi_1 = 6$, $\xi_2 = 2.2$; hence, the depletion layer penetrates 4×10^{-4} cm into the high-resistivity side (parent material) of the junction, and only 1.4×10^{-4} cm into the lower-resistivity (diffused) part of the wafer.

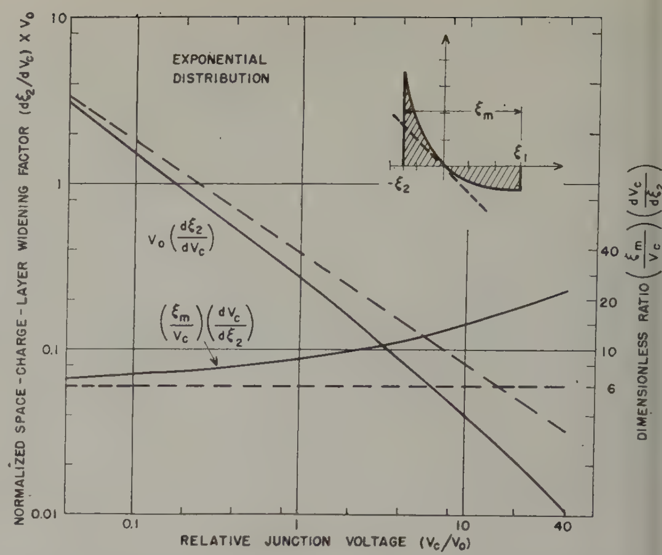

Fig. 6—Normalized space-charge layer widening factor as a function of relative junction voltage for exponential impurity distribution.

Space-Charge-Layer Widening Factor

In applying these results to the collector junction of a transistor, another quantity of interest is the space-charge-layer widening factor,[9] i.e., the rate of penetration with voltage of the depletion layer into the base region. Depending upon type of transistor structure, either the variable, or uniform, concentration side of the junction could be used as the collector. For example, a diffused-base structure might be represented by the impurity distribution shown in *Fig. 2c,* with the uniform-concentration side as the collector, whereas a rate-grown structure might be approximated by the distribution shown in *Fig. 2a* with the uniform-concentration side acting as the base region.

In any case the space-charge-layer widening factor, (dx_1/dV_c) or (dx_2/dV_c), can be calculated quite simply from the equations given in the Appendix. As an example, *Fig. 6* shows the variation of the normalized space-charge-layer widening factor V_0 $(d\xi_2/dV_c)$ with normalized voltage (V_c/V_0), for penetration into the variable concentration region of the exponential impurity distribution of *Fig. 2c*. Note the more rapid departure of the space-charge-layer widening factor from that of the uniformly-graded junction (dotted curve) as the depletion layer becomes increasingly unsymmetrical with increasing voltage. This variation is in contrast with that of the capacitance with voltage, which does not show any appreciable departure from the uniformly-graded behavior until the junction has become extremely unsymmetrical. Also shown in *Fig. 6* for comparison, is the dimensionless ratio (ξ_m/V_c) $(dV_c/d\xi_2)$ for both the exponential and uniformly graded junctions. For the uniformly-graded junction this ratio is 6, as shown by the horizontal dotted curve in *Fig. 6,* whereas for an abrupt junction, with penetration into the lower conductivity region the ratio[10] is 2. The *larger* this ratio relative to 6 the *smaller* the penetration relative to that of a uniformly-graded junction.

Acknowledgment

The assistance of J. Lawrence and F. Harbaugh in carrying out some of the numerical calculations is gratefully acknowledged.

APPENDIX

By employing the normalized coordinate system of *Fig. 2* of the text, Poisson's equation may be written in the form

$$\frac{d^2V}{d\xi^2} = -V_0 \frac{N(\xi)}{N_0} \tag{A-1}$$

$$\text{where } V_0 \equiv (N_0 x_0^2\, q_e/\epsilon_0\, \epsilon_r). \tag{A-2}$$

By substituting the appropriate forms of $N(\xi)/N_0$ in Eq. (A-1) and integrating twice with respect to ξ, an expression is obtained for $V(\xi)$ with two arbitrary constants. The constant arising from the first integration is evaluated by specifying that the electric field $(dV/d\xi)$ shall vanish at two values of ξ, ξ_1 and $-\xi_2$, (where ξ_1 and ξ_2 are positive numbers). The second constant, representing the zero of potential, arbitrarily may be set equal to zero, since only potential *difference* is of interest in the final results. Then the difference in potential between ξ_1 and $-\xi_2$, representing the junction voltage V_c, is related to the normalized depletion-layer width $\xi_m \equiv (\xi_1 + \xi_2)$.

This process will be illustrated for the hyperbolic distribution of *Fig. 2b* of the text, and corresponding equations simply will be quoted for the exponential distribution of *Fig. 2c*. In the case of the graded-abrupt distribution of *Fig. 2a,* two separate solutions to Eq. (A-1), one valid for $\xi \leq 1$ and the other for $\xi \geq 1$, are matched by requiring continuity of both electric field and of potential at $\xi = 1$.

Hyperbolic Distribution

Substituting $N(\xi)/N_0 = -[\xi/(1+\xi)]$ from Eq. (2) of the text, in Eq. (A-1) and integrating once yields

$$\frac{dV}{d\xi} = V_0\,[\xi - \ln(1+\xi) - B], \tag{A-3}$$

where B is the first constant of integration. Integrating again and setting the second constant of integration equal to zero,

$$V(\xi) = V_0 \left\{(\xi^2/2) + (1+\xi)\,[1 - \ln(1+\xi)] - B\xi\right\}. \quad \text{(A-4)}$$

Imposing the boundary conditions on $(dV/d\xi)$ yields

$$B = [\xi_1 - \ln(1+\xi_1)] = [-\xi_2 - \ln(1-\xi_2)], \quad \text{(A-5)}$$

which provides a relation between ξ_1 and $-\xi_2$ and also relates B to either ξ_1 or ξ_2 for use in Eq. (A-4). The potential difference V_c between ξ_1 and $-\xi_2$ can be calculated from Eq. (A-4), evaluated once at ξ_1 and once at $-\xi_2$:

$$V_c \equiv [V(-\xi_2) - V(\xi_1)] = V_0 \left\{(\xi_2^2 - \xi_1^2)/2 + (B-1)\cdot(\xi_1+\xi_2) + (1+\xi_1)\cdot\ln(1+\xi_1) - (1-\xi_2)\cdot\ln(1-\xi_2)\right\}.$$

Alternatively, by first introducing B from Eq. (A-5) into (A-4) when evaluating $V(\xi_1)$ and $V(\xi_2)$ separately, a very much simpler form can be obtained for V_c:

$$V(\xi_1) = V_0\,[1 + B - (\xi_1^2/2)]$$

$$V(-\xi_2) = V_0\,[1 + B - (\xi_2^2/2)]$$

and

$$V_c = (V_0/2)\,[\xi_1^2 - \xi_2^2] \quad \text{(A-6)}$$

Finally, the normalized depletion-layer width is simply

$$\xi_m \equiv (\xi_1 + \xi_2)$$

Thus, V_c is related to ξ_m through Eqs. (A-5), (A-6), and (A-7).

As a numerical example, let $\xi_2 = 0.9$; then Eq. (A-5) indicates that $B = 1.4$. Solving the second part of Eq. (A-5) for ξ_1 (by trial-and-error or by graphical means) yields $\xi_1 = 2.71$. Substituting these results in Eqs. (A-6) and (A-7) then yields

$$V_c = 3.26\ V_0$$

for

$$\xi_m = 3.61.$$

Exponential Distribution

The corresponding equations for the exponential distribution defined by Eq. (3) of the text are:

$$\frac{dV}{d\xi} = V_0\,[\epsilon^{-\xi} + \xi - B] \quad \text{(A-8)}$$

$$V(\xi) = V_0\,[(\xi^2/2) - \epsilon^{-\xi} - B\,\xi] \quad \text{(A-9)}$$

$$B = (\xi_1 + \epsilon^{-\xi_1}) = (\epsilon^{\xi_2} - \xi_2) \quad \text{(A-10)}$$

$$V_c = V_0\cdot(\xi_1+\xi_2)\cdot\left[(B-1) - \frac{1}{2}(\xi_1 - \xi_2)\right] \quad \text{(A-11)}$$

$$\xi_m \equiv (\xi_1 + \xi_2) \quad \text{(A-12)}$$

In this case B also appears in the final result for V_c, but the numerical procedure is quite similar to that described above.

Graded-Abrupt Distribution

For the graded-abrupt distribution, assuming always that $\xi > 1$ i.e., that the depletion layer extends at least partially into the uniform-concentration region, the corresponding equations are:

$\xi \geq 1$	$\xi \leq 1$	
$\dfrac{dV}{d\xi} = V_0(\xi - B_1)$	$\dfrac{dV}{d\xi} = [(\xi^2/2) - B_2)]$	(A-13)
$V(\xi) = V_0[(\xi^2/2) - B_1\xi + C_1]$	$V(\xi) = [(\xi^3/6) - B_2\xi + C_2]$	(A-14)
$B_1 = \xi_1 \geq 1$	$B_2 = (\xi^2/2)$	(A-15)

Equating the two solutions for $(dV/d\xi)$ and $V(\xi)$ respectively, at $\xi = 1$ yields

$$\xi_2^2 = (2\xi_1 - 1),\ \xi_1 \geq 1 \quad \text{(A-16)}$$

and

$$(C_2 - C_1) = (\xi_2^2/2) - \xi_1 + \frac{1}{3} = (1/6) \quad \text{(A-17)}$$

Then,

$$V_c \equiv [V(-\xi_2) - V(\xi_1)] = V_0\left\{(1/3)\xi_2^3 + (1/2)\xi_1^2 + (1/6)\right\} \quad \text{(A-18)}$$

and

$$\xi_m = (\xi_1 + \xi_2) \quad \text{(A-19)}$$

Space-Charge-Layer Widening Factor

Depending upon which direction of depletion-layer penetration is of interest, the junction potential V_c may be differentiated with respect to either ξ_1 or ξ_2, noting that ξ_2 also is a function of ξ_1 (or vice versa). For example, consider the case of the exponential distribution with penetration into the region of variable concentration. In Eq. (A-11), V_c is expressed as a function of ξ_1, ξ_2, and B with the latter further related to ξ_1 and ξ_2 through Eqs. (A-10)'

Differentiation of Eq. (A-11) with respect to ξ_2 yields

$$\frac{dV_c}{d\xi_2} = V_0\left\{\left[1 + \frac{d\xi_1}{d\xi_2}\right]\cdot\left[(B-1) - \frac{1}{2}(\xi_1 - \xi_2)\right] + (\xi_1+\xi_2)\cdot\left[\frac{dB}{d\xi_2} + \frac{1}{2} - \frac{1}{2}\frac{d\xi_1}{d\xi_2}\right]\right\}, \quad \text{(A-20)}$$

The two derivatives appearing in this equation may be evaluated from Eq. (A-10)

$$\frac{dB}{d\xi_2} = (\epsilon^{\xi_2} - 1);\ \frac{d\xi_1}{d\xi_2} = \frac{(\epsilon^{\xi_2} - 1)}{(1 - \epsilon^{-\xi_1})},$$

and these results together with Eqs. (A-10) and (A-11) may be substituted back in (A-20) to yield finally:

$$\frac{dV_c}{d\xi_2} = V_0\left\{\left[\frac{(V_c/V_0)}{1 - \epsilon^{-\xi_1}}\right] + \xi_m\left[(\epsilon^{\xi_2} - 1) + \frac{1}{2} - \frac{1}{2}\left(\frac{\epsilon^{\xi_2} - 1}{1 - \epsilon^{-\xi_1}}\right)\right]\right\}$$

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An Electronic Model of a Nerve Cell

L. D. HARMON* and R. M. WOLFE*

An electronic model is described which simulates many of the gross operational functions of living nerve cells. The properties of temporal and spatial summation, variable threshold and refractory period, inhibition, and all-or-none output are included. A four-transistor circuit comprising a monostable multivibrator, amplifier, and emitter-follower is used to simulate these neural functions. An analysis of the circuit and its operation is presented. This circuit can be viewed as an analog computer which generates a set of input-output functions similar to those of the neuron. As such, these models can be used to investigate modes of organization and information flow which may possibly exist in biological systems.

[Tear sheets of this article are available on written request]

The nerve cell or neuron is the basic building-block of the nervous system. As such it is ultimately responsible for the incredibly complex behavior of the brain—for intelligence, learning, and imagination. Typically occupying a volume of 10^{-7} cc. and consuming about a billionth of a watt, each of these elements has logical properties similar to those of computer elements. In combination these neurons produce systems which utilize frequency, amplitude, and pulse interval modulation. In the central nervous system there appear to be frequency and phase detectors, time delays, resonant loops, coincidence gates and the like. It is these properties, giving rise to "intelligent" processing of information, that we wish to model and to study.

Although the complete transmission characteristics of the living neuron are not fully known, many gross behavioral parameters are reasonably well understood.[1] Because of this incomplete state of our knowledge of neurophysiology and neuroanatomy, simulation of nerve cells with models can at best be only vague and approximate. Nevertheless, the creation and use of models based on the known functions may help to further our understanding and hence provide a useful research tool. Studies have been made using chemical models[2], electronic circuits[3], [4], and computer simulation.[5] The present model, a transistorized printed circuit, is more complete and flexible than its predecessors.

Neural Properties to be Simulated

The biological nerve cell is an electro-chemical device, utilizing ionic flows in semi-permeable protoplasmic membranes to produce and propagate currents. These currents are the neural signals which travel along discrete pathways in the cell at rates of from one to over one hundred meters a second. It is the set of input-output signal relationships of this nerve cell that we wish to simulate, replacing the chemical system with an electronic one. If the information processing parameters are accurately known and preserved, we may hope to retain logical and functional equivalence in the model.

In the simplest terms a neuron may be considered to be an electro-chemical black box, essentially a binary-output transducer, having two kinds of input and one output. It is binary only in the sense that for a given internal state and set of input conditions, it either fires (transmits an output signal) or it does not. It is a transducer in the sense that, independent of the nature of the input signal (it may be electrical or chemical for instance) a unique standardized electrical output is produced if any output occurs at all. The two types of input are excitatory and inhibitory. Of course, there need not be only two input connections or only one output connection to any one cell; usually there are many transmission paths to and from each neuron. Because of complex interacting properties internal to the element, it cannot be thought of as a simple binary switch. It is in fact these very properties which give rise to the complicated behavior we wish ultimately to understand.

The gross input-output properties of a neuron, greatly simplified, are described below. These are the functions incorporated in the electronic model.

I. Input

A. Excitation: Certain input connections to a neuron will, if sufficiently energized, always fire the neuron if certain conditions are met. These conditions are as follows:

1. Threshold—A neuron may be fired if the triggering energy supplied to it exceeds a certain threshold value within a time limit. There are input pulses which have insufficient amplitude to cause firing no matter how long they last. This amplitude threshold is variable, being a function of the previous history of firing of the neuron, and is typically on the order of a few tens of millivolts.
2. Refractory Period—Immediately after firing, a neuron's threshold rises effectively to infinity and for a period of a few milliseconds, no available input signal can fire the neuron again. This absolutely refractory period is followed by a relatively refractory phase. During this second phase an exponentially decreasing threshold is observed, approaching the pre-firing threshold and reaching it after a few tens of milliseconds.
3. Summation—Two or more input pulses, each of insufficient energy to excite a neuron can be integrated by the cell so that firing occurs.

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To be successful this summation must occur within a maximum time, typically on the order of a millisecond or so. Since these inputs may arrive via different pathways, there can be both spatial and temporal summation.

B. Inhibition: Certain input connections other than excitatory ones can, while energized, inhibit firing of the neuron.

II. Output

The output of a neuron is "all-or-none". If firing occurs, then a pulse of standard amplitude and duration is produced. There are exceptions, but as a first approximation we may consider the energy per output pulse to remain constant.

An interconnection between two neurons occurs at a junction which is called a synapse. These synaptic connections are thought to be variable as a function of time and use, the probability of transmission between two neurons being increased with use and diminished with disuse. However, this property has not yet been proved to exist, and is not included in the present model. A synaptic connection is known to be unilateral, allowing transmission in only one direction, contrary to the behavior of the neural fiber proper which will propagate an applied pulse bilaterally. This one-way propagation between neurons is assured in the electronic model simply by the asymmetrical nature of the active electronic elements.

The input and output parameters described above can be easily visualized by referring to *Fig. 1*. The model can be represented as a four-terminal device as indicated. Suppose that the input signal, $E(t)$, is first passed through an imperfect integrator, i.e., one having a finite time-constant. This can be realized with a low-pass *R-C* circuit. Let $V(t)$, the integrated voltage, be added to $-W(t)$ which is an output derived* voltage having some standby value, W_0. $U(t)$, the sum of these two voltages may then be thought of as the internal threshold of the model. We may assign some arbitrary value to this function, (say $U(t) \leqq 0$), which is necessary and sufficient to cause firing and a consequent output pulse, $O(t)$.

The external threshold of the device is then measured by that value of input as a function of time, $E(t)$, which is required to cause $U(t)$ to fall below zero. There is dependence here both on amplitude and duration, i.e., energy; also as in the physiological nerve, both a minimum time and a minimum level are required for firing. Suppose that the integration time-constant is τ and the input pulse is of length T. The following relationships will hold:

$$V_{max} = E_{max}\,(1 - e^{-T/\tau})$$

or

$$E_{max} = \frac{V_{max}}{1 - e^{-T/\tau}}$$

thus for firing,

$$|E_{max}| \geq \left|\frac{W}{1 - e^{-T/\tau}}\right| \qquad (1)$$

*The feedback function of *Fig. 1*, generating $W(t)$ is a linear operator applied to $O(t)$.

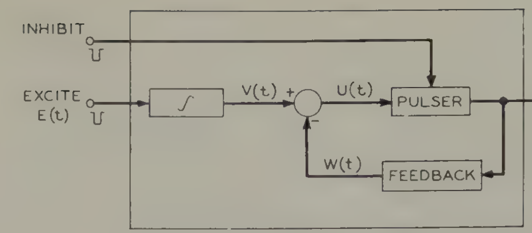

Fig. 1—Simplified neuron model.

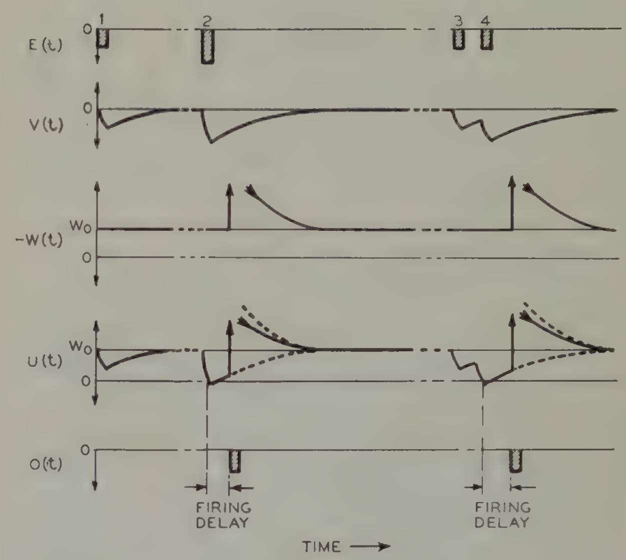

Fig. 2—Input-Output relationships.

The condition $|E_{max}| \geqq |W_0|$ is always necessary for firing, irrespective of integrator time-constant or pulse-length. It can be seen from Eq. (1) that the following approximate relations also hold:

$$|E_{max}| \geq |W| \qquad T \gg \tau$$

$$|E_{max}| \geq (\tau/T)\,|W| \qquad T \ll \tau$$

$$|E_{max}| \geq \frac{|W|}{0.632} \qquad T = \tau$$

The phenomenon of summation can be shown to occur if two pulses of $|E_{max}| < |W_0|$ occur close enough together in time. The necessary and sufficient condition here is that the interval between two subthreshold pulses be short enough (given E_{max}, T, and the integrator characteristics) so that $V(t)$ has not decayed to less than $W(t) \mid - V(t)_{max}$ at the onset of the second pulse. Thus the second pulse will produce

$$V(t) \geq [\,|W(t)| - |V(t)_{max}| + |V(t)_{max}|\,] \geq |W(t)| \qquad (2)$$

and firing occurs.

These relationships are schematized in *Fig. 2*. The first input pulse is of insufficient amplitude-duration to cause an output pulse. However $E_2(t)$ is capable of bringing $U(t)$ below zero, and after a firing delay, produces a unique output pulse, $O(t)$. Consequently $W(t)$ causes a short refractory period followed by an exponential decay toward resting threshold W_0.

Pulses #3 and #4 are each too small to cause firing,

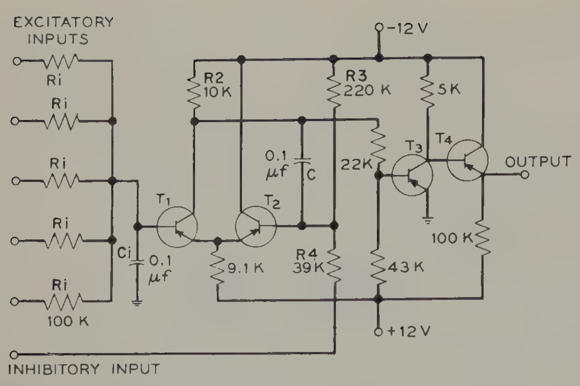

Fig. 3—Model neuron circuit

but in conjunction are able to summate and thus produce an output pulse.

The Artificial Neuron

Any proposed model of a neuron must possess most of the above properties in order to be useful in studies of nerve nets. Since investigation of such networks involves large numbers of neurons, the model must ideally be small in size, low in cost, and low in power consumption. These considerations lead to the use of transistors as the active elements. The circuit to be described is designed around a modification of a conventional emitter-coupled monostable multivibrator. An output amplifier is provided to prevent load variations from affecting the operation of the multivibrator and to alloy the circuit to drive a number of similar circuits.

A schematic diagram of the artificial neuron is given in *Fig. 3*. Transistors T_1 and T_2 form the emitter-coupled monstable multivibrator, T_3 amplifies and inverts, and T_4 is an emitter-follower to provide a low impedance output. At rest, T_1 is cut off, T_2 and T_4 are in the active state, and T_3 is in saturation. The emitters of T_1 and T_2 are at a potential W_0 which represents the quiescent threshold of the circuit. Inputs are applied through resistances to the base of T_1 and are integrated by the action of capacitor C_i. If we call the voltage on the base of T_1, $V(t)$, then $U(t)$ representing the base to emitter voltage of transistor T_1, will be $V(t) - W(t)$. A negative-going pulse applied to the input will cause $V(t)$ to go negative and hence $U(t)$ to approach zero. When $U(t)$ becomes negative, transistor T_1 turns on and the firing action is initiated.

Transistor T_1 turning on causes its collector voltage to suddenly change in a positive direction. Since a sudden change cannot take place in the voltage across capacitor C the positive change is coupled to the base of transistor T_2, turning T_2 off. The current through R_2 that was flowing through T_2 is now diverted through T_1 and holds T_1 on during the pulse.

Capacitor C now starts to discharge so that the base voltage of T_2 decreases exponentially toward $-V\dfrac{R_4}{R_3+R_4}$ where V is the magnitude of the negative supply. The emitters are near ground potential because T_1 is on. When the base voltage of T_2 goes slightly negative, T_2 turns on and T_1 turns off. The time of discharge of C thus determines the width of the output pulse.

The turnoff of T_1 causes a negative-going transient to be developed at the base of T_2. Since T_2 is now on and acting like an emitter-follower, the negative-going transient is coupled to the emitters and serves to increase the threshold of the circuit.

The absolute refractory period of the circuit has two components. One is measured by the duration of the output pulse; the other is that interval immediately following, during which the largest input possible in the system cannot fire the circuit. The relative refractory period is determined by the remainder of the negative transient appearing on the emitters. Its duration is a function of the recharging rate of C.

Inhibition is accomplished by applying a negative pulse directly to the base of T_2 through resistor R_4. This pulse is applied to the emitters in the normal manner and its amplitude proportionally increases the threshold. The circuit returns to its resting state with the normal refractory time constant when the inhibition signal is removed.

Analytical expressions for the quiescent threshold, pulse width, refractory time constant and free-running period are derived in the appendix. A general discussion of design considerations of the circuit, taking into account variation of transistor parameters, is also given.

Summary and Conclusions

Many of the gross functions believed to hold for living neurons have been approximated by an electronic device. The 4-transistor model exhibits variable threshold, inhibition, summation, and all-or-none output. Roughly forty milliwatts are dissipated by the 4 cubic inch device which can be built in quantity for less than $10.

This circuit, actually an analog computer simulating the input-output functions of its biological counter-

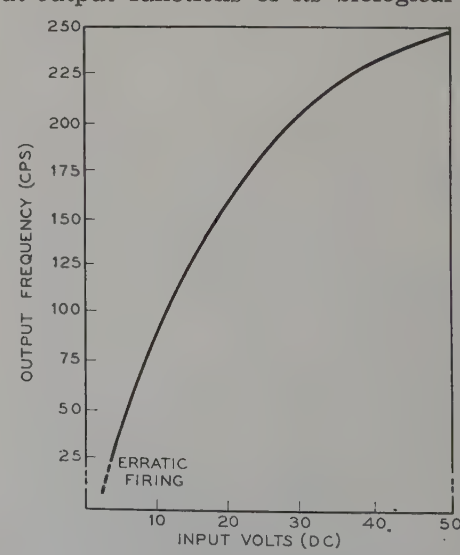

Fig. 4—Characteristic output frequency

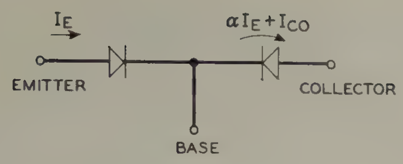

Fig. 5—Equivalent circuit of transistor

part, can be connected with others to form chains and nets. One unit will drive up to one hundred others without serious deterioration of output waveform or level.

The artificial neuron can be used to give either single pulse outputs or variable frequency pulse trains, depending on the nature of the input. A typical *d-c* input *vs.* frequency-output characteristic is shown in *Fig. 4*. The former (single pulse) mode of operation is useful for simulating functions of neurons which process neural pulses, i.e., network operation, while the latter mode of operation can be used to model peripheral or transducer functions.

An example of this latter class of operations would be the simulation of such peripheral receptors as retinal elements. A suitable transducer such as a photoresistive cell (e.g., CdSe) can be used to drive a model neuron, thus initiating pulse trains which can subsequently be processed by other units.

The present model has an input integrating time-constant of 2 milliseconds and a refractory time-constant of about 4 milliseconds approximating corresponding values in the biological neuron. Quiescent threshold is from one to five volts (depending on the number of inputs connected) while the output pulse level is ten volts. These levels are many times greater than those found in nerve tissue (thresholds there are typically 5-10 *mv* and output spike potentials are approximately 50 *mv*) but the *ratios* between threshold and output levels are commensurate. These ratios in part determine input summation characteristics where several cell outputs combine. The output pulse duration is about 6 milliseconds, considerably greater than the action-spike duration in biological nerve, but can be shortened at will by a suitable differentiating network.

These models are being used to study some of the possible modes of operation of simple structures in the retina and in the cochlea. It is hoped that such investigation will be useful in understanding or in predicting neurological behavior. Despite great difficulties that exist in drawing very rigorous analogies between the biological cell and its imitation, sufficient rough similarities exist to make systemic experimentation interesting.

Appendix

The equivalent circuit shown in *Fig. 5* is used in deriving analytical expressions for the threshold, output pulse width, refractory time constant and free-running period. This model neglects the resistances found in the usual representation of a transistor. The transistor is in the *off* state if both diodes are back biased, it is in the active state if the emitter diode is forward biased while the collector diode is back biased, and it is in the saturated state when both diodes are forward biased. Only transistors T_1 and T_2 and their associated components influence the factors for which expressions are to be derived.

Quiescent State Calculations

Proceeding with the calculation of the quiescent threshold, W_0, *Fig. 6* shows the monopulse circuit with both transistors replaced by their equivalent circuits. Since T_2 is in the active state, the circuit has been further simplified by representing the emitter diode of T_2 by a short circuit. Writing the nodal equations for this circuit, assuming zero input voltage, we get

$$\alpha_2 I_{E2} + I_{CO2} + \frac{W_0 + E}{R_4} + \frac{W_0}{R_4} = I_{E2}$$

$$\frac{E - W_0}{R_2} + I_{EO1} = I_{E2}$$

$$\frac{X_0 + E}{R_1} + \frac{X_0}{R_5} = I_{CO1}$$

$$\frac{V_0}{R_i} + I_{CO1} + I_{EO1} = 0$$

Solving, we get

$$W_0 = \frac{(1-\alpha_2)\,R_{eq} - \dfrac{R_2\,R_{eq}}{R_3}}{(1-\alpha_2)\,R_{eq} + R_2}\,E + \frac{(1-\alpha_2)\,R_2\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\left(I_{E01} - \frac{I_{C02}}{1-\alpha_2}\right) \quad (3)$$

$$X_0 = -\frac{R_5}{R_1+R_5}\,E + \frac{R_1 R_5}{R_1+R_5}\,I_{CO1} \quad (4)$$

$$V_0 = -R_i\,(I_{CO1}+I_{EO1}) \quad (5)$$

where $$R_{eq} = \frac{R_3\,R_4}{R_3 + R_4}$$

If the circuit is to be stable in the quiescent state, V_0 must be more positive than W_0, therefore

$$\frac{\dfrac{R_{eq}}{R_3}\,R_2 - (1-\alpha_2)\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\,E + \frac{R_2\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\,I_{C02} > R_i\,I_{C01} + \left[R_i + \frac{(1-\alpha_2)\,R_2\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\right] I_{E01}$$

In practice $R_i \gg \dfrac{(1-\alpha_2)\,R_2\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}$ so the above may be simplified to

$$\frac{\dfrac{R_{eq}}{R_3}\,R_2 - (1-\alpha_2)\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\,E + \frac{R_2\,R_{eq}}{(1-\alpha_2)\,R_{eq} + R_2}\,I_{C02} > R_i\,(I_{C01} + I_{E01}) \quad (6)$$

giving us a practical stability criterion.

Firing State Calculations

The equivalent circuit for the neuron in the firing state is shown in *Fig. 7*. When the neuron is in the firing state, T_1 is on or saturated and the capacitor C is discharging and holding T_2 cut off. In order that the pulse length be as independent as possible of the input pulse and the parameters of the transistors, T_1 should be saturated. For T_1 to remain saturated in the absence of an input pulse, W_1 must be greater than zero. If the transistor is saturated, then

$$W_1 = \frac{\frac{1}{R_2} + \frac{1}{R_5+R_6} - \frac{1}{R_1}}{\frac{1}{R_i} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_5+R_6}} E$$

$$\text{where } \frac{R_i}{\frac{R_2}{1-\alpha_1} + R_i} E \leq W_1 \leq \frac{\frac{\alpha_1}{R_2} + \frac{1}{R_5+R_6} - \frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_5+R_6} + \frac{\alpha_1}{R_2}} E \qquad (7)$$

The voltage at the base of T_2 is at W_0 before firing and goes positive by an amount $W_1 - X_0$. It then starts to discharge exponentially toward $-E/2$ with a time constant $\frac{R_4 C}{2}$. The base voltage of T_2 may be written as

$$Y(t) = \left(\frac{E\,R_4}{R_3 + R_4} + W_0 + W_1 - X_0\right) e^{-\frac{t}{R_{eq}C}} - \frac{E\,R_4}{R_3 + R_4}$$

The output pulse will terminate when $Y(t)$ equals W_1, since T_2 will turn on at that time and initiate the turn-off transient. Therefore we can solve for T by setting $Y(t)$ equal to W_1

$$T = R_{eq}\,C \ln\left(1 + \frac{W_0 - X_0}{W_1 + \frac{E\,R_4}{R_3 + R_4}}\right) \qquad (8)$$

When T_2 turns on, T_1 turns off and its collector goes from W_1 to X_0. This change in voltage is coupled to the base of T_2 by the capacitor C. T_2 acts like an emitter follower and drives the emitter of T_1 negative a like amount. This negative transient decays with a time constant RC as follows:

$$R\,C = \left(R_1 + \frac{1}{\frac{1}{R_{eq}} + \frac{1 - \alpha_2}{R_2}}\right) C \qquad (9)$$

If a d-c voltage exceeding the quiescent threshold W_0 is applied to the input, the circuit will free-run. The period of this oscillation is composed of two parts; one, the duration of the pulse, is

$$t_i = R_{eq}\,C \ln\left(1 + \frac{V_i - X_0}{W'_i + \frac{E\,R_4}{R_3 + R_4}}\right) \qquad (10)$$

$$\text{where } W'_i = \frac{\left(\frac{1}{R_2} + \frac{1}{R_5+R_6} - \frac{1}{R_1}\right) E + \frac{V_i}{R_i}}{\frac{1}{R_i} + \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_5+R_6}}$$

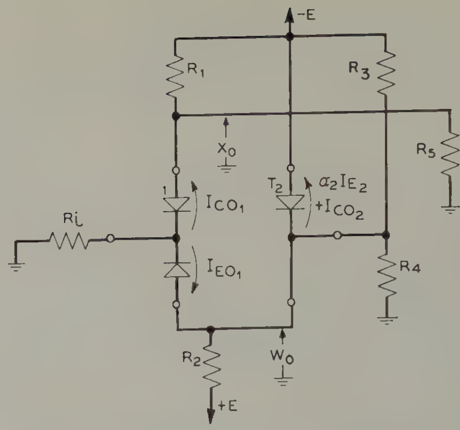

Fig. 6—Equivalent circuit of neuron at rest

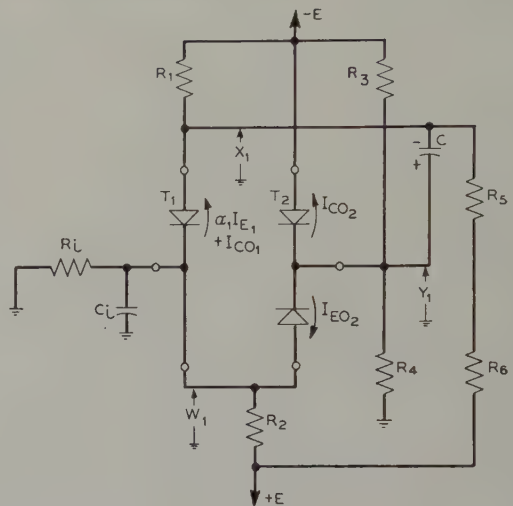

Fig. 7—Equivalent circuit of neuron in firing state

The other part is the time between pulses, which is

$$t_2 = RC \ln\left(\frac{X_0 - W_0}{V_i - W_0}\right) \qquad (11)$$

The time of the period is the sum of these parts.

The expressions for the pulse length (Eq. 8), refractory time constant (Eq. 9), and free running period (Eqs. 10 and 11) are only approximate since the effects of I_{CO} and I_{EO} are neglected so that the expressions might be simpler. The effect of the inclusion of these parameters is to shorten the various times since the presence of these currents tends to cause faster discharge of the capacitor.

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Alloying With Controlled Spreading in Silicon Transistors*

Part 1

J. ROSCHEN† T. J. MILES† C. G. THORNTON†

Surface spreading of the electrodes in silicon alloy transistors greatly affects the performance and uniformity of the device characteristics. With conventional radiant alloying techniques and low edge dislocation density silicon, electrode areas may increase more than 100 percent. In the silicon surface-alloy transistor, used in this investigation, spreading was found to occur on the heating portion of the alloying cycle and to be strongly dependent on orientation for (111) oriented material. Use of (100) and (110) oriented silicon essentially eliminates spreading, but results in shorted transistors. On lapped surfaces and thick silicon oxide films, the identity and the restrictive action of the crystal plane is lost. These spreading problems are alleviated through an extremely rapid rate of heating: on the order of 9000 to 18,000° C/min.

[Tear sheets of this article are available on written request]

As a result of improvements in the bulk properties and the concurrent reduction of edge dislocations in single crystals of silicon, as with germanium,[1], [2], [3] surface spreading on alloying has become more evident. On (111) oriented material this results in triangular and hexagonal electrodes, as shown in *Fig. 1.* Such spreading is of particular importance in high-frequency silicon transistors.

Spreading in silicon-alloy transistors must be eliminated or greatly reduced if electrical performance is to be uniform and optimum. The small electrode sizes, thin base-widths, and low injection efficiencies and high recombination velocities in silicon require rigid control of geometrical parameters. With conventional equilibrium alloying techniques and low edge dislocation densities, the area of silicon electrodes may increase more than 100 percent. Spreading is more evident in (111) oriented material which must be used for planar-parallel junctions in transistors.

This article discusses spreading and its effect on the electrical parameters of silicon transistors. It describes the important factors that affect spreading, and how, through the control of these factors at alloying, spreading is alleviated with a significant improvement in electrical characteristics.

Spreading in Transistors

The importance of spreading control on alloying in transistors is readily demonstrated by the *p-n-p* surface-alloy transistor (*SAT*). In this transistor electrochemical jet-etching, aluminum electrode evaporation, and surface alloying techniques offer close control of geometrical parameters. The internal geometry of this transistor is illustrated in *Figs. 2, 3, 4,* and *5. Fig. 5* is a cross-section photomicrograph of a completed transistor (whisker wires forcibly removed) illustrating the planar-parallel junctions and narrow (0.00007″) base width.

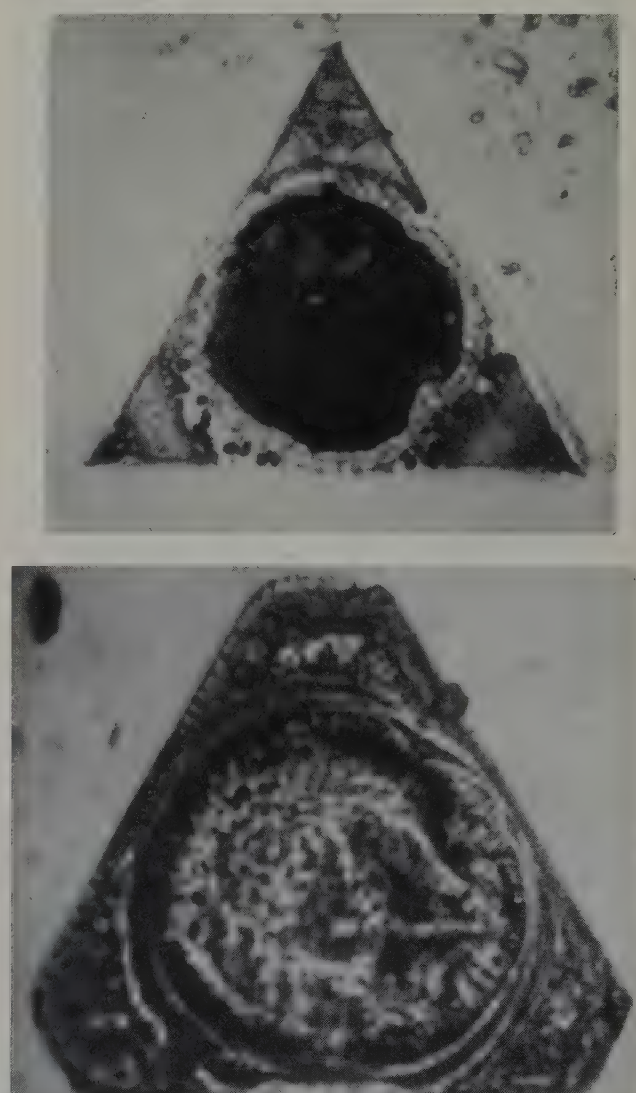

Fig. 1 —Alloyed electrodes showing evidences of orientation dependence of spreading on (111) silicon. Magnification ≈250X.

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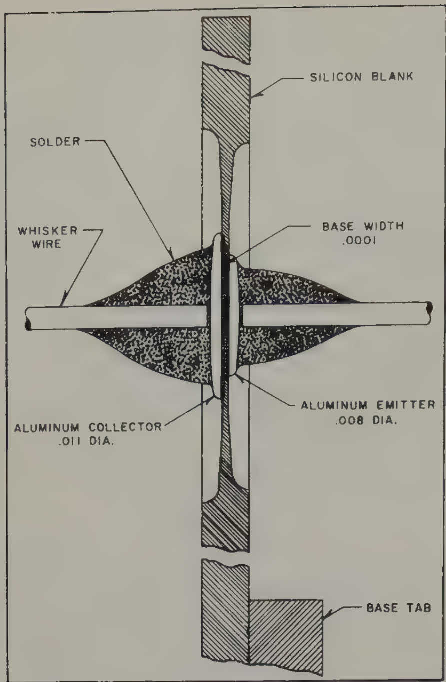

Fig. 2 —Internal geometry of a silicon surface-alloy transistor.

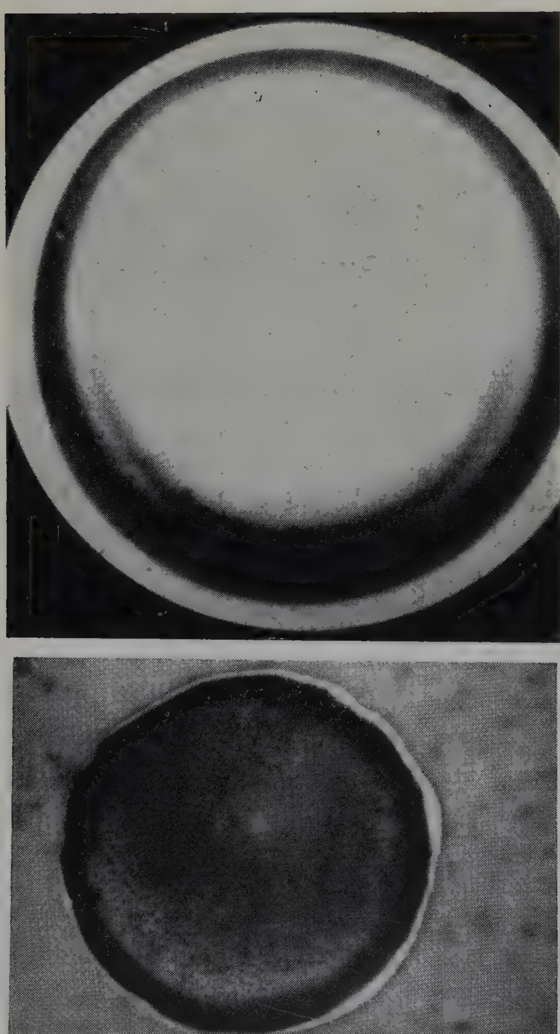

Fig. 3 —Etched silicon showing smooth surface in etched region. Magnification $\approx$100X (Top). Evaporated aluminum electrode. Magnification $\approx$250X (Bottom).

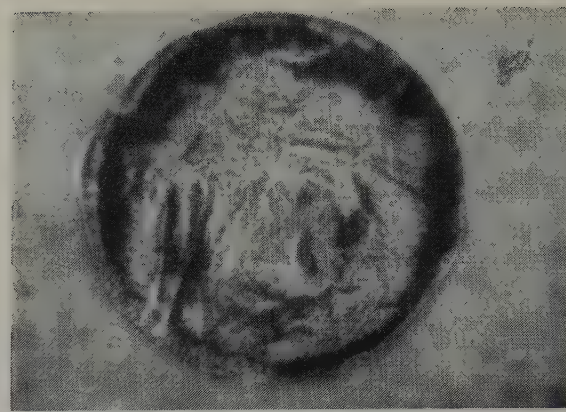

Fig. 4A—Alloyed Electrode.

When spreading occurs on both the emitter and collector electrodes, the vertices of the triangular electrodes are out of phase by 60° due to the restrictive action of the (111) terminal planes, as is illustrated in *Fig. 6*. The degree of spreading can vary considerably from unit to unit because of non-uniform silicon. In addition to the change in electrode configuration, the alloying depth is greatly affected. Such a phenomenon is undesirable in transistors from the standpoint of uniformity and optimum performance.

Parameters such as current gain, frequency response, output capacitance, punch-through voltage, and base spreading resistance are affected by spreading. The effect of uncontrolled spreading on the distribution of punch-through voltage is shown in *Fig. 7*. To induce spreading, the alloying was performed in a dry hydrogen atmosphere at a slow alloying rate of 450°C/min. to a terminal temperature of 900°C. With pre-alloying base-width controlled to an accuracy of $\pm$0.035 mil, the results as plotted on these graphs show that punch-through voltage and current gain are affected more by the degree of spreading than by the pre-alloying base width. As the degree of spreading decreases, the number of units exhibiting shorts and

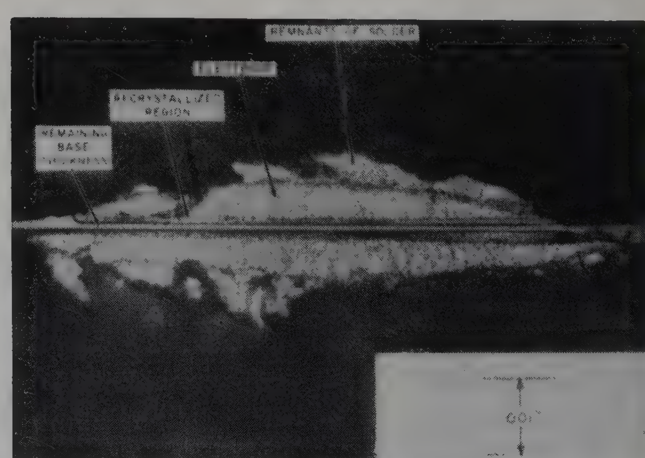

Fig. 5 —Cross-section of the electrode region of a completed transistor (Whisker wire forcibly removed).

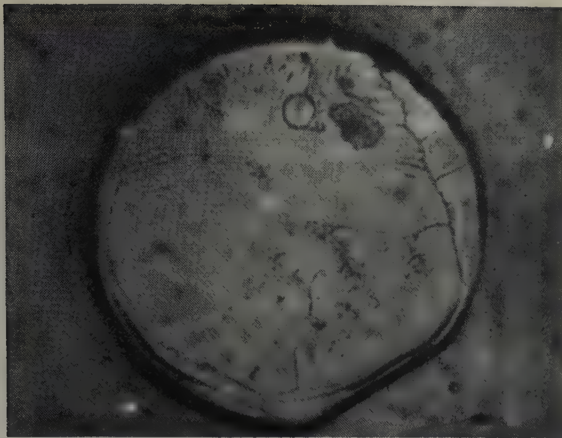

Fig. 4B—Recrystallized region after removal of aluminum silicon eutectic. Magnification ≈250X.

low punch-through voltage increases. This increase in the number of defective units is due to the fact that penetration during the alloying process is, among other things, a function of the mass of aluminum over a given area. Because of the variation in spreading, the mass per unit area varies considerably. If the mass (or height) of aluminum per unit area can be controlled during the alloying cycle, the depth of penetration is quite predictable.

Surface Effects

In an attempt to eliminate spreading, numerous surface treatments were tried without success. However, some of the results are of interest and are reported below.

Contrary to results obtained with indium alloyed on germanium by Pankove[2], a mechanically disturbed surface produced by scratches in the *SAT* does not noticeably limit spreading. This is illustrated in *Fig. 8*, where it has not been inhibited by a scratched surface.

If alloying takes place over a mechanically lapped surface or a thick silicon oxide film, the identity and restrictive action of the crystal plane is lost and spreading assumes a circular configuration (*Fig. 9*).

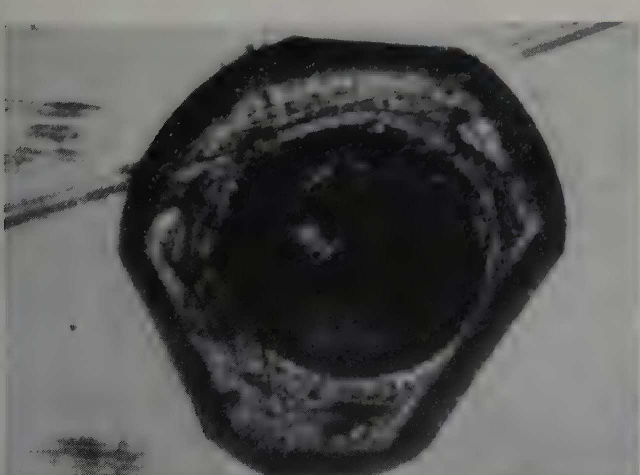

Fig. 8 —Alloyed electrode with spreading on a scratched surface. Magnification ≈300X.

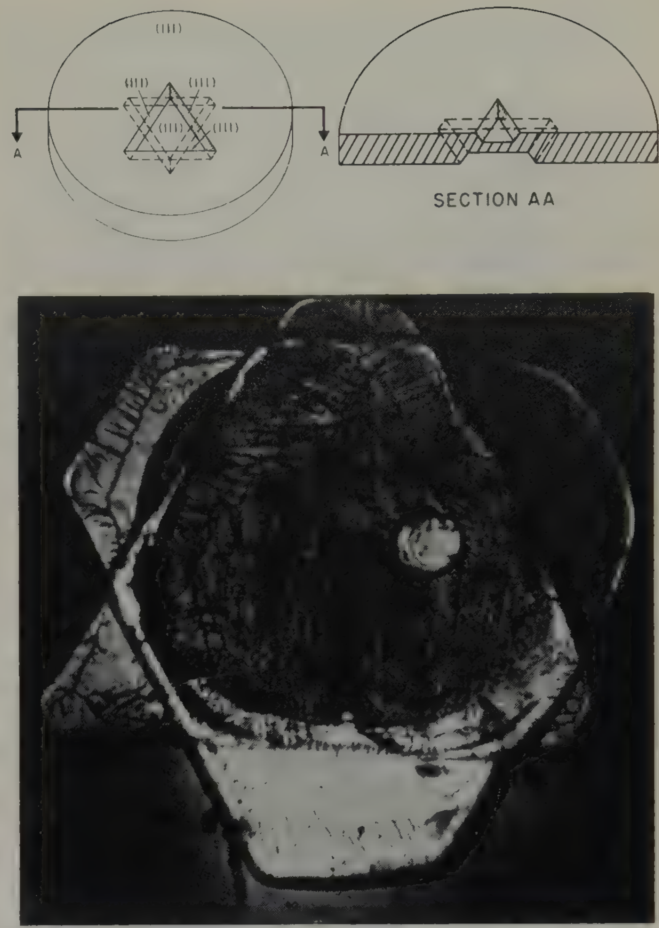

Fig. 6 —Drawing (A) and photomicrograph of a transistor with light transmitted through the recrystallized region (B) Illustrating a 60° phase shift between opposing electrodes.

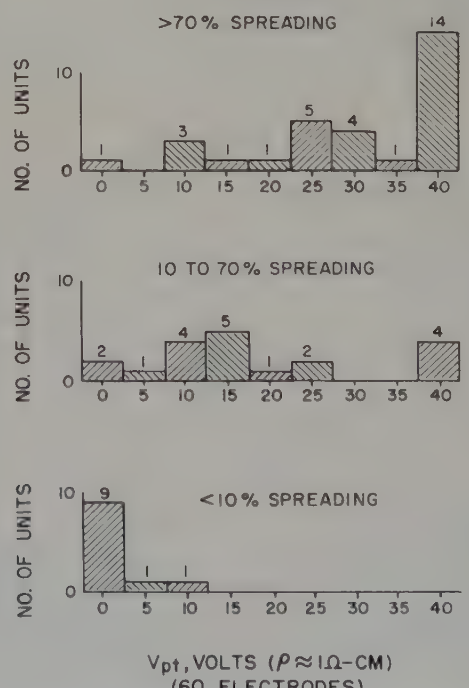

Fig. 7 —Effect of spreading on the distribution of punch-through voltage.

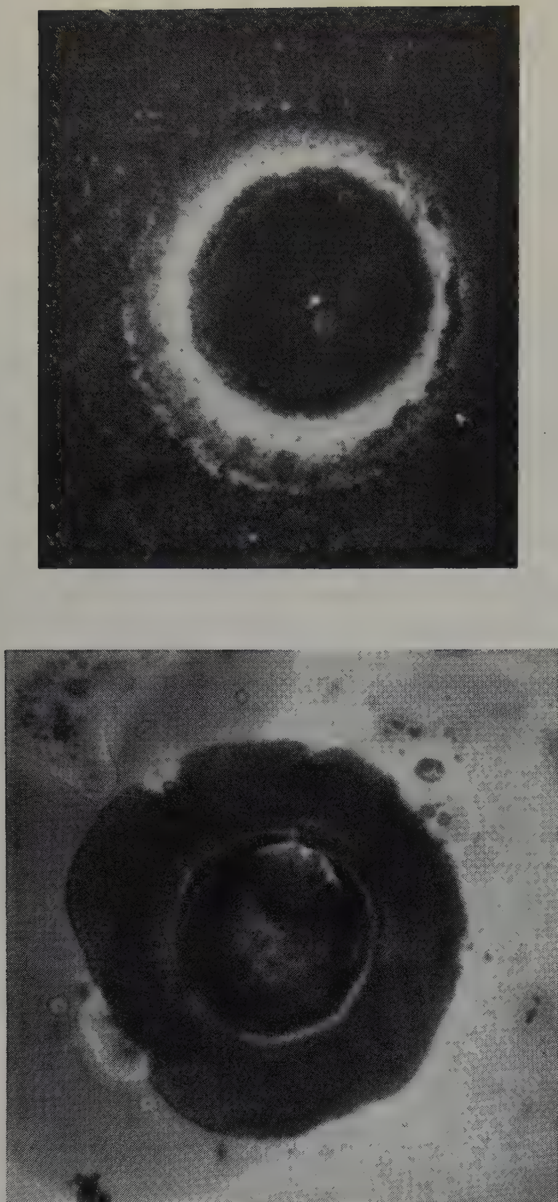

Fig. 9 —Non-orientation dependence of spreading on a lapped Surface (Top) and a thick oxide surface (Bottom). Magnification ≈150X.

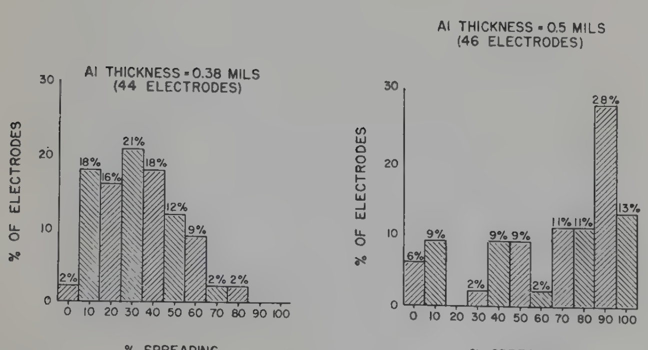

Fig. 10—Effect of evaporated aluminum electrode thickness on the distribution of spreading.

Electrode Composition and Mass

Attempts to affect the dissolution rate and to inhibit spreading through the addition of tin, lead, and 12% silicon to the aluminum indicated no substantial reduction in spreading. However, any increase in the mass or thickness (for constant electrode area) of evaporated aluminum resulted in increased spreading.

An increase of aluminum thickness from 0.38 mil to 0.5 mil resulted in an average change in spreading from 33% to 68% (*Fig. 10*).

Crystal Axis

To eliminate the 60° out-of-phase relationship that exists between the emitter and collector electrodes in (111) orientated material, (100) and (110) orientated materials were tried. Results were as expected, (1) the spreading problem was essentially eliminated, and (2) all transistors were shorted because of non- planar parallel alloying and the narrow base-width. When the sample was viewed in cross-section, the junctions were clearly not planar-parallel.

Misorientation of 2 degrees from the (111) plane failed to eliminate spreading. Further misorientation tends to aggravate the short-through and non-planar-parallel junction problem.[4] A limit of 1 degree is deemed necessary for reasonable yields for narrow base width transistors of this type.

Edge Dislocations

In germanium, it has been established that edge dislocations inhibit spreading.[1], [2], [3] Similar results have been obtained in silicon. It is believed that a dislocation is a region where excess energy is available to speed up the dissolution of the silicon. In this region the equilibrium concentration of the silicon in aluminum is reached more rapidly resulting in reduced spreading and deeper alloying.

The partial and complete limiting effect of edge dislocations on spreading is shown in *Fig. 11*. These samples were first etched to reveal the dislocation pits.* Then 8-mil diameter by 0.5-mil thick aluminum electrodes were evaporated, some on edge dislocation pits, others on regions free of pits. To induce spreading, the samples were alloyed in a dry hydrogen atmosphere at a heating rate of 450°C/min. up to a terminal temperature of 900°C. They were held at 900°C for 2 minutes and cooled at a rate of approximately 200°C/min. The samples were photographed before and after alloying to permit correlation of spreading with etch pits. An over-lay of these two photographs indicated spreading was present where etch pits were absent, and limited where etch pits were present.

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*Etch pits were revealed after 4 hours in the following modified CP-4 etchant. 6 *ml* HNO_3 (70%), 2 *ml* glacial acetic acid, 7 *ml* HF (48%), 0.25 *gm* $Cu(NO_3)_2 \cdot 3\,H_2O$, and 250 *ml* H_2O. On completion of etching a nitric acid rinse was used to remove the deposited copper.

Statistical evidence is also available indicating that when areas of ingots having more numerous dislocations, as the outer edge of an ingot, are used, spreading is reduced and more shorts are experienced. A difference in dislocation density between the center and edge of a wafer cut from an ingot grown by the "Czockralski" pulling process is shown in *Fig. 12*. The density of the center of this wafer is <100 pits/cm^2 and of the order of 10^4 pits/cm^2 within 1/8 inch of the edge. The difference in spreading between the low dislocation density center and the high dislocation density edge of a silicon wafer is given below:

	Center	*Edge*
Dislocation density, pits/cm^2	150	860
Average spreading, %	100	78

In addition to producing preferential deep alloying and shorts,[5] edge dislocations affect the minority carrier lifetime[6] and electrical characteristics, such as the diode breakdown voltage.[7], [8] Therefore, a high incidence of dislocations is not the answer to the problem.

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[6] A. D. Kurtz, S. A. Kulin, and B. L. Averbach, "Effect of Dislocations on the Minority Carrier Lifetime in Semiconductors", *Phys. Rev., Vol. 101*, 1285, (1956).

[7] A. C. Chynoweth and G. L. Pearson, "Effect of Dislocations on Breakdown in Silican P-N Junctions", *J. Appl. Phys. 29*, 1103 (1958).

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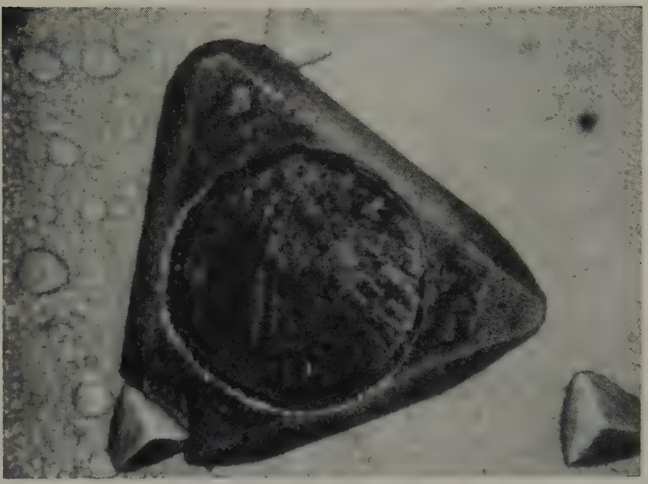
[*To Be Concluded*]



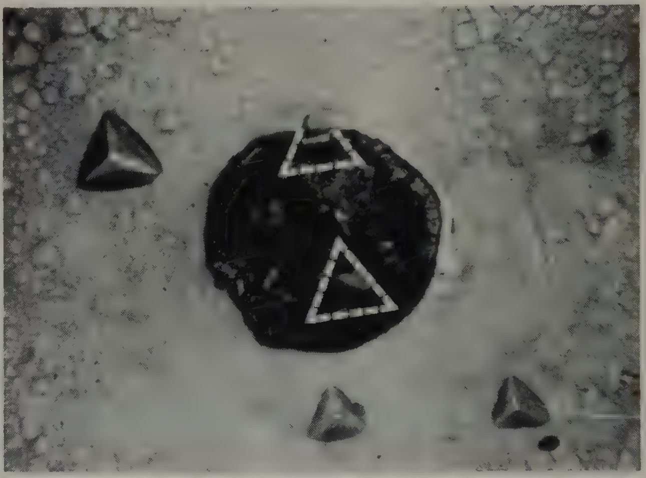
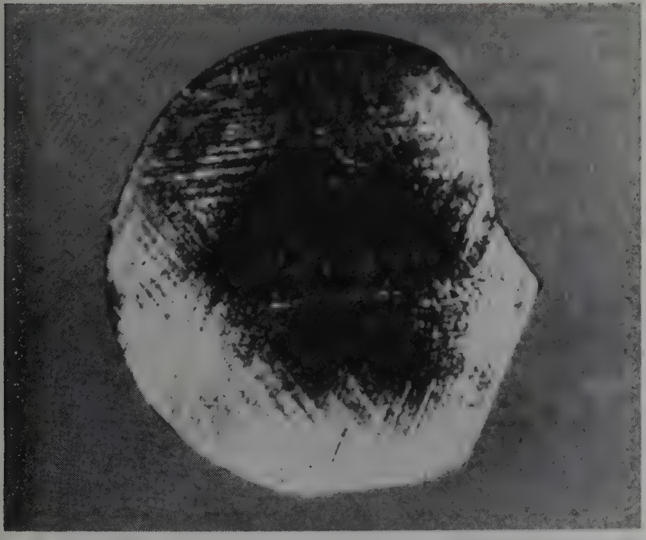


Fig. 11—Alloyed electrodes showing partial and complete (Top and Bottom, respectively) limiting effect of edge dislocation etch pits on spreading. Magnification ≈250x. (White dash marks indicate presences of dislocation etch pits under electrodes).



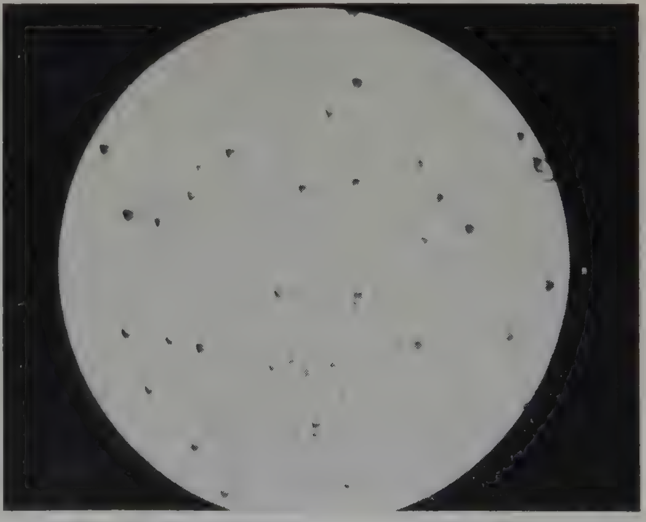


Fig. 12—Variation of edge dislocation etch pit density across wafer. Magnification ≈2X (left). Dislocation etch pits in Center region. Magnification ≈75X (right).

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A Graphic Solution for Thermistor Characteristics	Control Engrg Feb 1959	Two nomograms simplify calculations of thermistor characteristics from given data or measurements.	H. G. Parke
Meter Indicates Diode Reverse Recovery Time	Elec Mfg Feb 1959	A meter technique for diode reverse recovery time measurement eliminates the need for an oscilloscope.	R. Fekete
Radiation Effects Data Sheets	Elec Mfg Feb 1959	Includes effects on semiconductors. Tables list components; flux rate, *nv;* integrated dose, *nvt;* and results.	No Author
Role of Semiconductors in the Army Micromodule Program	Electronic Design Feb 18 1959	Aim of program, division of its phases, and technical requirements for micro-transistors and micro-diodes.	I. J. Ross
Two-Dimensional Transistor Packaging	Electronic Design Feb 18 1959	Steps in connections of a diffused-base transistor to wiring on a printed circuit board. Integration of hermetically and non-hermetically sealed units on a p/c board.	J. W. Lathrop J. R. Nall R. J. Anstead
A Monostable Circuit Using a Transistor	Electronic Engineering (Brit) Feb 1959	A pulse generating circuit is described using a simple pulse transformer, the characteristics of which can have considerable latitude.	H. Stinton
A 1-*MC* Transistor Decade Counter	Electronic Engineering (Brit) Feb 1959	A transistor decade counter is described which accepts input pulses at a maximum repetition frequency of 1.3 *mc*.	C. G. Bradshaw
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A Regenerative Modulator Frequency Divider Using Transistors	Electronic Engineering (Brit) Feb 1959	A 100 *kc* crystal controlled oscillator followed by two frequency dividers giving 10 *kc* and 1*kc* outputs.	F. Butler
Transistor Bias Design From Thermal Incremental Properties	Electronic Engineering (Brit) Feb 1959	Explicit formulae for the design of single stage bias networks are given. Theoretical expressions and procedures are discussed in detail.	L. M. Vallese
Designing Transistor Circuits—Sequential Circuits, Pt. 2	Elec Equip Engineering Feb 1959	One-shot circuits and free-running oscillators can provide sequential logic. Various types of oscillator circuits are discussed.	R. B. Hurley
Properties of Infrared Radiation	Elec Equip Engineering Feb 1959	Tutorial article discusses basic theories and formulas of electro-magnetic radiation, black body and real body radiation and absorption.	C. R. Betz
How Transistors Can Replace Relays	Elec Equip Engineering Feb 1959	Transistor can be used to replace relays in many applications. Basic *d-p-d-t* transistor relay and practical circuit are described.	C. D. Todd
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Understanding Zener Diodes	Electronic Industries Feb 1959	Control of the breakdown voltage, and the factors which determine output voltage changes with fluctuations in regulator current.	J. R. Madigan
Diode Phase Detectors	Elec & Rad Engineering (Brit) Feb 1959	A theory common to diode phase-meters and phase-sensitive detectors is worked out for two types of push-pull detectors.	S. Krishnan
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Thermistor Date Chart	Electronics Feb 13 1959	Chart gives thermistor resistance value at desired application temperatures for standard thermistor types.	A. E. Lawson Jr.

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Telemetry Demodulator Using Modified AND Gate	Electronics Feb 20 1959	Input circuit to pulse-position telemetry demodulator is a modified two-input semiconductor diode AND gate.	L. Weisman
Four-Transistor Inverter Drives Induction Motor	Electronics Feb 20 1959	*D-C* Motors can be replaced with induction motors by employing transistors as controlled switches to provide 2-phase square-wave outputs from a single *d-c* source.	W. H. Card
TV Sound Detector Uses Drift Transistor	Electronics Feb 20 1959	Draft-Transistor slope detector operates in an oscillating mode. Superior performances compared with passive detector is obtained at low signal levels; equivalent performance is obtained at larger signal levels.	M. Meth
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Two-Terminal Solid-State Switches	Electronics Feb 27 1959	Tabulation of important characteristics of commercially available *p-n-p-n* semiconductor switching diodes.	T. P. Sylvan
Transistors Provide Computer Clock Signals	Electronics Feb 27 1959	Except for oscillator, all transistors operate on either saturated or cutoff state.	S. Schoen
Stability of Semiconductors in Microminiature assemblies	Electronic Design Feb 18 1959	Circuit for obtaining surface characteristic. Scope patterns observed for various ambient atmospheres in term of *n* and *p* type surface.	J. Stinchfield O. L. Meyer
Photoconductivity as a Function of Optical Absorption	Jl Appl Phys Feb 1959	A theoretical analysis of the dependence of photoconductivity upon optical absorption is presented.	A. M. Goodman
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Vaporization-Crystallization Method for Growing CdS Single Crystals	Jl Appl Phys Feb 1959	A self-refining method for growing three different forms of CdS single crystals is described together with fabrication details of the zone furnace employed.	D. R. Boyd Y. Sihvonen
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Diffusion of Impurities into Evaporating Silicon	Jl Appl Phys Feb 1959	Steady-state impurity distributions are produced when impurities are diffused into a piece of silicon, the surface of which is evaporating.	R. L. Batdorf F. M. Smits
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Field Effect at High Frequency	Jl Elec & Cont (Brit) Feb 1959	Theory of the field effect at high frequencies using the same basic assumptions as Garrett (1957) with more complete conditions at the back surface.	F. Berg
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Transmission Line Analogue of a Drift Transistor	Philips Res Rep Feb 1959	A transmission line that is governed by the same differential equations as a drift transistor is discussed.	J. te Winkel
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A Fast Method of Reading Magnetic-Core Memories	Philips Tech Rev No 7 Feb 10 1959	Review and discussion of various memory systems. Particular type of system with transistor switch/amplifier described.	H. J. Heijn N. C. de Troye
Electrical Conduction in Crystals and Ceramics of WO_3	Physical Review Feb 1 1959	WO_3 behaves like an impurity semiconductor having a saturation region below 740°C and becoming intrinsic above 910°C.	S. Sawada G. C. Danielson
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Some Properties of Green and Red-Green Luminescing CdS.	Physical Review Feb 15 1959	A series of electro-optical experiments at room temperature have been made with two types of high-purity, single crystals of CdS	Y. T. Sihvonen D. R. Boyd C. D. Woelke
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Transistor Noise Factor Tester	Semiconductor Products Feb 1959	Description of a simple and reliable instrument for measuring audio Noise Factor of transistors.	J. J. Davidson
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Intermetallic Semiconductors	Semiconductor Products Feb 1959	Methods of synthesis, purification and single crystal growth are described; also properties and applications.	H. T. Minden
On the Doping of the Semiconductor Compound $CoSb_3$	Sov Phys Sol State Jan 1959	The effect of thirteen impurity elements on the thermoelectrc and electric properties of the semiconductor compound $CoSb_3$ was investigated.	L. D. Dudkin N. Kh. Abrikosov
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Dependence of the Electrical Conductivity of Selenium on Pressure—I	Sov Phys Sol State Jan 1959	The dependence of the electrical conductivity of monocrystals and polycrystals of selenium on pressure was investigated at different temperatures.	P. T. Kozyrev

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Measurement of the Dependence of the Hall Effect in *N*-Type Germanium on Pressure for Pressures up to 10,000 Rg/cm^2	Sov Phys Sol State Jan 1959	Study of the Hall effect in Semiconductors, primarily in germanium with known impurities, as a function of pressure in a wide temperature range.	A. I. Likhter T. S. D'yakonova
Crystalline CdS Gamma-Radiation Receivers	Sov Phys Sol State Jan 1959	Development of a technique of producing specimens of CdS sufficiently sensitive to X-rays and gamma rays without the use of phosphors, amplifiers and intensifiers.	I. D. Konozenko V. I. Ust'yanov
Investigation of Intercrystalline Energy Barriers in Thin Films of Cadmium Sulfide by Irradiation of the Films with Low-Energy Electrons	Sov Phys Sol State Jan 1959	In this work the variation in the resistance of very thin films of CdS (10^{-7} to 10^{-5} cm) was investigated when the films were irradiated with energies from 0 to 15 ev.	Li Chih-chien
Dependence of the Induced Conductivity on the Energy of Electrons in the Films of Cadmium Sulfide and Selenide During Bombardment With Slow Electrons	Sov Phys Sol State Jan 1959	Variation of the electrical conductivity was measured in films of CdS and CdSe about 10^{-4} cm thick, obtained by vacuum deposition, during bombardment with electrons with energies from 0 to 15 ev.	Li Chih-chien
The Effect of Surface Recombination on the Photoconductivity on Semiconductors	Sov Phys Sol State Jan 1959	Derivation of the conditions for "diffusion" layers, and calculation of the photoconductivity of semiconductors.	L. G. Biv
Some Quantitative Relationships of the Process of the Donor-Acceptor Reaction in Metal Alloys	Sov Phys Sol State Jan 1959	Confirmation of the donor or acceptor role of the individual components of metallic solid solutions, and quantitative formulas.	I. M. Frantsevich D. F. Kalinovich I. I. Kovenskii M. D. Smolin
Calculation of Transient Processes in Transistors	Sov Phys Sol State Jan 1959	Transient conductivity of a transistor is calculated taking into effect the final value of internal *R*, the *emf* of the excitation source, the collector capacitance, and the load resistance.	A. A. Grinberg
Cyclotron Resonance in Semiconductors With Complex Equipotential Surfaces	Sov Phys Sol State Jan 1959	A method of calculating the galvanomagnetic effects for equipotential surfaces of any form is proposed.	Yu. A. Firsov
Characteristic Times of Steady-State Electron Processes in Semiconductors	Sov Phys Sol State Jan 1959	Object of research was to investigate the characteristic times for the case of non-equilibrium steady-state generation.	G. M. Guro

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PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from May 22, 1956 to Aug 14, 1956. In subsequent issues, patents issued from Aug. 14, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

May 22, 1956

2,746,121 Conditioning of Semiconductor Translators—A. E. Anderson. Assignee: Bell Telephone Laboratories. A method of electrically forming a transistor to improve its electrical characteristics which comprises applying forming energy near the collector, monitoring the collector-to-base voltage while anamalous charge carriers are injected into the region, and terminating the forming operation when the collector-to-base voltage has fallen to a predetermined value.

2,746,122 Method of Stabilizing the Resistance Characteristics of Selenium Rectifier Cells—H. J. Zygmunt, L. K. Hedding. Assignee: Westinghouse Air Brake Company. A method of comprising the steps of repeatedly exposing a cell to a temperature below 0° F for several minutes during each exposure period, and reforming the cell after each exposure except the last.

2,747,023 Marker Impulse Generator for Signaling Systems—K. Hagenhaus. Assignee: Siemens & Halske (A German Corporation). A marker impulse generator device which has a relatively small number of circuit closure or switching means as compared with the number of outlets serving for the utilization of the marker impulses produced.

2,747,111 Coupling Circuit for Semiconductor Devices—W. R. Koch. Assignee: Radio Corporation of America. A system including a first and a second signal circuit terminal, means providing a point of fixed reference potential for said system, a transistor, a network for conveying signal variations from said first terminal to said terminal, and means for providing an energizing potential for the system.

May 29, 1956

2,747,254 Manufacture of Selenium Rectifiers—W. H. Harding. Assignee: Westinghouse Electric Corporation. A method of treating selenium rectifier cells by applying a constant alternating voltage across a rectifier cell and a capacitor in series.

2,747,971 Preparation of Pure Crystalline Silicon—C. C. Hein. Assignee: Westinghouse Electric Corporation. The production of single crystals of silicon by employing gold-silicon alloy for progressively melting a body of polycrystalline silicon under such conditions that the alloy melts said silicon at one face of said body and rejects pure silicon at the other face, such rejected silicon depositing on a single crystal of silicon and building up thereon.

2,748,041 Semiconductor Devices and Their Manufacture—H. W. Leverenz. Assignee: Radio Corporation of America. A device comprising a semiconductive body of one conductivity-type, a layer of substance alloyed and diffused into one surface thereof whereby a rectifying barrier and a layer of opposite conductivity-type are formed within said surface, and a channel formed in said alloyed layer whereby a plurality of diffusion junctions are formed.

2,748,235 Machine For Automatic Fabrication of Tetrode Transistors—R. L. Wallace, Jr. Assignee: Bell Telephone Laboratories. A device to determine the exact location on a minute bar of semiconductor material of one conductivity type, a still more minute intermediate zone of opposite conductivity type, and to bond one or more electrodes to this zone; said machine performing said operations in a manner suitable for production purposes.

2,748,274 Transistor Oscillator With Current Transformed Feedback Network—A. R. Pearlman. Assignee: Clevite Corporation. An oscillator including a pair of transistors connected in push-pull relationship, and a secondary winding on a feedback transformed inductively coupled to a primary winding thereon and connected across the transistor inputs to supply regenerative feedback energy thereto which varies with the load current.

2,748,325 Semiconductor Devices and Methods for Treating Same—D. A. Jenny. Assignee: Radio Corporation of America. A device including a semiconductive body having fuzed to a surface thereof a body of impurity-yielding material, *p-n* junction adjacent to said impurity-yielding body, and a film of insulating material upon the surface of said device.

2,748,326 Semiconductor Translators and Processing—R. C. Ingraham. Assignee: Sylvania Electric Products Incorporated. A method of producing stable point-contact germanium devices which includes the steps of etching the exposed surface of a mounted germanium body, baking said mounted body for a prolonged period, coating said surface with a fluid silicone, assembling the point-contact device within a cartridge, and hermetically sealing said cartridge.

2,748,349 Fabrication of Junction Transistors—E. Dickten, Jr., R. P. Riesz, R. L. Wallace, Jr. Assignee: Bell Telephone Laboratories. A method of determining the exact location of an intermediate zone of opposite conductivity type on a semiconductor body of which the end portions are of one conductivity type.

June 5, 1956

2,749,463 Solid State Television Pickup Tube—J. R. Pierce. Assignee: Bell Telephone Laboratories. An electronic camera tube having a target consisting of a continuous wafer of silicon or germanium and having the property that a light image incident thereon produces at the surface thereof locally trapped hole-electron pairs for developing a surface contact potential in the semiconductor representative of said light image.

2,749,471 Electron Device With Semiconductive Target—E. S. Rittner. Assignee: North American Philips Company Inc. An electron discharge tube having a target electrode comprising a pair of spaced electrically terminal electrodes with an active photo-conductive semiconductive metallic sulphide element therebetween.

2,749,488 Light Cells or Rectifiers—S. E. Mayer. Assignee: International Standard Electric Corporation. A cell comprising a container having an inert atmosphere, an insulating seal at one end thereof, a pair of leads sealed to said insulating seal and extending within said container, a junction-type semiconductor die mounted between said leads, and a transparent window in said container to permit light to fall upon said die.

2,749,493 Speed Regulating and Current Limit Motor Control System—P. M. Fisher. Assignee: Cutler-Hammer Incorporated. Apparatus designed to provide a speed regulating and current limit control system characterized by low steady state error, high system stability and sharp current limit action.

June 12, 1956

2,750,452 Selectivity Control Circuit—H. C. Goodrich. Assignee: Radio Corporation of America. In combination a resonant signal circuit, a transistor, means for varying

* Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

a control voltage in series with said resonant circuit to vary the effective emitter-to-base resistance and the Q of said resonant circuit.

2,750,453 Direct Current Amplifier—R. L. Pritchard. Assignee: General Electric Company. An amplifier comprising a passive input device having an external-stimulus-controlled resistance, a transistor with a current amplification factor less than unity, an output load device and a single unidirectional voltage source.

2,750,456 Semiconductor Direct Current Stabilization Circuit—F. D. Waldhauer. Assignee: Radio Corporation of America. A direct current stabilizing amplifier circuit which enables the utilization therein of semiconductor devices having dissimilar characteristics and in which *a-c* degeneration may be minimized.

2,750,507 Transistor Oscillator Circuit—R. R. Law, H. Johnson, L. J. Giacoletto, L. E. Barton. Assignee: Radio Corporation of America. An oscillator circuit including a transistor, a frequency determining circuit for said oscillator which is tunable to alternating current of a predetermined frequency, and means for controlling the alternating current flow because the base and the emitter in phase relation with said first named current for sustained and stable oscillation.

2,750,508 Transistor Oscillator Circuit—F. D. Waldhauer. Assignee: Radio Corporation of America. An oscillation generator including a transistor, a first and second reactive impedance elements connected with the emitter and base respectively, a third impedance element connected with said collector, and means connecting said impedance elements to a common point to form a T-network providing regenerative collector-to-base feedback.

2,750,509 Pulse Generators—R. O. Endres. Assignee: Radio Corporation of America. An astable pulse generator comprising a transistor, transistor electrode operating potential sources, a delay line coupled between the collector and a common junction point for propagating voltage waves to the end of said line and for reflecting and applying said waves to said collector electrode to vary the current conducting condition of the transistor, and means for deriving output pulses across a resistor at a rate determined by said delay line.

2,750,510 Free Running Square Wave Generator—R. P. Moore, R. O. Endres. Assignee: Radio Corporation of America. A generator having a predetermined repetition rate and including a transistor, an impedance element coupling the emitter electrode, the action of said delay line causing a variation in the current conduction of said transistor for determining said repetition rate.

2,750,540 Selenium Rectifiers and Their Manufacture—E. G. Wald Kotter, A. M. Hase. Assignee: Siemens Schuckertwerke Aktiengesellschaft (A German Corporation). A dry rectifier unit comprising a flexible base electrode of a maximum thickness of 0.01 mm., a flexible counter electrode and a flexible semiconductive layer between said electrodes and firmly joined therewith.

2,750,541 Semiconductor Translating Device—R. S. Ohl. Assignee: Bell Telephone Laboratories. A device consisting of a body of silicon or germanium, an integral surface layer thereon having electrical characteristics other than those of said body produced by bombardment thereof with ions of significant impurities.

2,750,542 Unipolar Semiconductor Devices—L. D. Armstrong, D. A. Jenny. Assignee: Radio Corporation of America. A device consisting of a semiconductor body having zones of *p*-type and *n*-type conductivity separated by a rectifying barrier, at least one of said zones having a free planar surface; in one of the zones a current path the width of which is defined by said barrier and said surface; and a pair of ohmic contact electrodes.

2,750,543 Crystal Diode Unit—H. M. Wadsworth. Assignee: None. In a crystal diode assembly, a cylindrical electrode, a crystal plate fixed on one end thereof, a second electrode, a spring wire filament attached at one end thereto and a hollow cylindrical casing of dielectric material.

2,750,544 Silicon Translating Devices and Methods of Manufacture—W. G. Pfann. Assignee: Bell Telephone Laboratories. A manufacturing method which comprises sustaining a glow discharge at atmospheric pressure between a body of silicon and an electrode, interrupting said discharge, mounting a limited area contact on the portion of the body contacted by said glow discharge, and discharging a condenser biased beyond the peak voltage of the device across the contact and the silicon body.

June 19, 1956

2,750,654 Miniature Rectifier—H. L. Owens. Assignee: U.S.A. (Dept of the Army). A method of fabricating a semiconductor device which includes the step of dipping a completed rectifier assembly and its leads in a thermoplastic medium where upon solidification said plastic forms a solid bead which encases and fixes a spacer, a semiconductor, and its leads, in position to form an integral device.

2,751,446 Automatic Gain Control Circuit for Transistor Amplifiers—C. C. Bopp. Assignee: Avco Manufacturing Corporation. A gain control circuit for a main transistor amplifier, said circuit including a direct current transistor amplifier and means for varying the collector-to-emitter impedance thereof.

2,751,497 Super-Regenerative Transistor Broadcast Receiver—R. S. Duncan. Assignee: Bell Telephone Laboratories. A radio receiver for operation over a predetermined frequency band which comprises a transistor oscillator, a regenerative feedback circuit, means for matching the amount of feedback to the current gain frequency characteristic of said transistor, whereby a constant level of oscillation is maintained over the entire frequency band of operation of the receiver.

2,751,498 Crystal Controlled Oscillator Circuit—M. E. Malchow. Assignee. Radio Corporation of America. A crystal controlled transistor oscillator circuit having a frequency determining means including an impedance element and a piezoelectric crystal serially connected between the base electride and a source of reference potential.

2,751,501 Transistor Oscillator—E. Eberhard. Assignee: Motorola Inc. A phase shift type oscillator including first and second transistors, a point of reference potential, a resistance-capacity phase-shifting feedback network, means for providing a 180-degree phase shift to a signal of selected frequency appearing across a resistive element connecting the emitter of the second transistor with the point of reference potential, and means for sustaining the oscillation at such a selected frequency.

2,751,527 Semiconductor Devices—E. G. Shower. Assignee: National Union Electric Corporation. A device consisting of a hermetically sealed semiconductive crystal and electrodes in contact therewith.

2,752,529 Point-Contact Semiconductive Device—J. W. Stineman Jr., S. A. Robinson. Assignee: Philco Corporation. A shock resistant point-contact semiconductive device having low-noise properties and mechanical stability even under adverse environmental conditions of contaminated atmosphere or excessive humidity.

2,751,545 Transistor Circuits—F. H. Chase. Assignee: Bell Telephone Laboratories. In combination, a rectifier for supplying current to a load circuit, a saturable reactor for supplying the current from a source, a transistor, and a current path between the saturating winding of said reactor and the collector electrode.

2,751,549 Current Supply Apparatus—F. H. Chase. Assignee: Bell Telephone Laboratories. In combination: a *d-c* source supplying a load circuit; an *n-p-n* transistor and a *p-n-p* transistor; means for controlling the current in said load circuit, and means for directly conductively connecting the base electrode of the first transistor to the collector of the second transistor.

2,751,550 Current Supply Apparatus—F. H. Chase. Assignee: Bell Telephone Laboratories. A circuit including one or more transistors that sets up across a load a substantially constant voltage having a desired magnitude.

June 26, 1956

2,752,541 Semiconductor Rectifier Device—E. F. Losco. Assignee: Westinghouse Electric Company. In combination: a metal body having a semiconductor device place inside a cavity therein, means for securing one of the terminal members of said device to said body, and means for closing and sealing the hollow.

2,752,542 Dry Plate Rectifier—E. Nitsche. Assignee: Siemens-Scheickertwerke Aktiengellschaft. A stack mounted dry-plate rectifier having spacer bushing on the central mounting rod of said stack, said bushings being interleaved with the rectifier plates.

July 3, 1956

2,753,495 Point-Contact Translators—J. F. Barry. Assignee: Bell Telephone Laboratories. A device including a pair of wires having chisel shaped ends which engage a semiconductive body in critically spaced relationship, a buffer mass of fluid material on the portion of said body engaged by said wires, and a resinous bead surrounding said body and buffer mass.

2,753,496 Complexes of Multielectrode Semiconductors—S. Tenzer. Assignee: None. A transistor having a disc-shaped member formed from an agglomeration of semiconductive granular particles making electrical contact with each other; and first, second and third electrodes, positioned in such a way so that a change of current between the first and third electrodes produces an amplified change in

the current flowing between the second and third electrodes.

2,753,497 Crystal Contact Rectifiers. A. Jenkins, A. Langridge. Assignee: Westinghouse Brake and Signal Company Ltd. A point-contact crystal diode assembly enclosed in a hermetically sealed tubular casing of insulating material.

2,753,501 Transistor Commutated Direct Current Motor—H. D. Brailsford. A commutatorless *d-c* motor having a centrifugal device, a rotor, driving windings, and transistors for energizing the driving windings under control of the control windings.

July 10, 1956
2,754,431 Semiconductor Devices—H. Johnson. Assignee: Radio Corporation of America. In a semiconductor device, means for varying the effective resistance of a portion of a semiconductive body within a current path defined between the base electrode and the emitter or collector electrodes, said means comprising a *p-n* rectifying junction electrode disposed adjacent to said current path.

2,754,455 Power transistors—J. I. Pankove. Assignee: Radio Corporation of America. A device including a cylindrical semiconductive body of one conductivity type having annular, coaxial zones of the other conductivity type, and heat radiating means, including a forced fluid cooling system.

2,754,456 Semiconductor Device and Method of Its Manufacture—O. Madelung. Assignee: Siemens Schuckertwerke Aktiengesellschaft. A device consisting of a body made of a binary compound of aluminum with an element of the second subgroup in the fifth group of the periodic system, and an aluminum oxide coating on the surfaces of said body.

July 24, 1956
2,756,285 Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A device comprising an enlongated semiconductive body having therein four longitudinally extending continuous zones, adjacent zones being of opposite conductivity type, and means for producing at the junction of said zones a space charge region which increases in thickness from one end of said body to the other.

2,756,374 Rectifier Cell Mounting—P. J. Colleran, A. C. English, F. P. Mulski. Assignee: General Electric Company. A cell mounting formed of component parts which may be fabricated at temperatures which would normally be destructive to the cell, and thereafter assembled under conditions which prevents injury to the cell as a result of heating operations employed in making the assembly.

July 31, 1956
2,756,483 Junction Forming Crucible—R. M. Wood. Assignee: Sylvania Electric Products Incorporated. Apparatus for alloying metal terminals to opposed surfaces of a slice of semiconductor.

2,757,243 Transistor Circuits—D. E. Thomas. Assignee: Bell Telephone Laboratories. A device which initiates the flow of emitter current in low-voltage low-power single battery transistor circuits without adversely affecting the operation thereof under steady state conditions, and which permits Class AB, B, or C operation of self-biased transistor oscillators.

2,757,286 Transistor Multivibrator—C. L. Wanlass. Assignee: NAA. A multivibrator circuit comprising a pair of transistors and a pair of diodes.

2,757,287 Stabilized Semiconductor Oscillator Circuit—T. O. Stanley. Assignee: Radio Corporation of America. In a transistorized circuit, means are provided for between the collector and base electrodes providing regenerative feedback for said device to sustain oscillation thereof over a range of frequencies.

2,757,289 Transistor Oscillator Circuit—A. Har'el, C. C. Cheng. Assignee: Radio Corporation of America. A transistor oscillator circuit including feedback means, the parameters of which are given by the following relationships

$$\frac{L_2}{L_1} = m; \frac{C_2}{C_1} = \frac{1}{2m}; \frac{C_3}{C_1} = \frac{m}{2}$$

where, with respect to the components of the circuit, L_1 and L_2 are the inductance of a first and second inductor respectively; C_1, C_2 and C_3 are the capacitances of a first, second and third capacitors respectively, and m is a constant.

2,757,322 Crystal Contact Devices—E. G. James. Assignee: General Electric Company Ltd. A device comprising a semiconductive body having a tapered portion, three metallic wire shaped members, and supports for the element and the contact members, said contact members in point-contact relationship with the crystalline element.

2,757,232 Full Wave Asymmetrical Semiconductor Devices—J. P. Jordan, A. D. Sheckler. Assignee: General Electric Company. A device comprising a wafer of semiconductive material, and a pair of discrete impurity diffused regions on one face of said wafer, said regions providing said wafer with two independent rectification barriers.

2,757,324 Fabrication of Silicon Translating Devices—G. L. Pearson. Assignee: Bell Telephone Laboratories. A silicon diode comprising a silicon wafer of *n*-type conductivity, an aluminum element bonded to the wafer and forming a rectifying connection therewith, and a gold-antimony alloy element bonded to said wafer and forming an ohmic connection therewith.

August 7, 1956
2,757,439 Transistor Assemblies—L. E. Burns. Assignee: Raytheon Manufacturing Company. A method of assembling a semiconductive device and encapsulating said device within a hardened protective housing.

2,757,440 Apparatus for Assembling Semiconductor Devices—J. N. Carman. Assignee: Hughes Aircraft Company. Adjustable apparatus for automatically and progressively stressing the elements of a point-contact semiconductor device to a predetermined value which may be varied by varying the adjustment of the machine.

2,758,206 Transistor Pulse Generator—D. J. Hamilton. Assignee: Hughes Aircraft Company. A transistor pulse generator for producing output pulses upon occurence of the zero reference cross-over point of an applied input signal.

2,758,208 Electric Frequency Dividers—H. Grayson. Assignee: International Standard Electric Corporation. A network consisting of an amplifier, a gating circuit, means for applying an input wave of a given frequency to control said circuit, and means for deriving from the output of said amplifier an output wave for applying said output wave at a periodicity equal to a sub-multiple of said given frequency to control said gating current.

2,758,261 Protection of Semiconductor Devices—L. D. Armstrong, J. I. Pankove. Assignee: Radio Corporation of America. A semiconductive device encased in plastic material, and a high resistivity resilient, chemically inert material in intimate contact with said device in order to protect predetermined portions thereof.

2,758,263 Contact Device—J. J. Robillard. Assignee: Telefonaktiebolaget L. M. Ericcson (A Swedish Corporation). A contact device having a plane-surfaced crystal, a layer having multiple perforations supported by said plane surface, and conductive second layer on said first layer.

2,758,264 Electric Rectifiers—K. A. Matthews, R. A. Hyman. Assignee: International Standard Electric Company. A semiconductor device having a base electrode and two rectifying electrodes connected by a single terminal spaced apart by a distance whereby the rectification ratio measured between the single terminal and the base electrode is the same as the ratio measured between the base electrode and either rectifying electrode taken by itself.

2,758,265 Selenium Rectifier—C. A. Escoffery. Assignee: International Telephone & Telegraph Company. A cell that uses a lacquer for an artificial barrier layer by means of which higher voltage discs can be obtained with a minimum number of rejects, said lacquer also enabling the forming time to be appreciably reduced.

2,758,266 Selenium Rectifier—W. F. Bonner, R. F. Durst, W. Lewanda, A. E. Machala. Assignee: International Telephone and Telegraph Company. A selenium rectifier having deposited on it a barrier layer of a solution of a high molecular weight linear polymeric carbonamide soluble in the lower aliphatic alcohols.

August 14, 1956
2,759,052 Amplifier Semiconductor Volume Compression System—A. A. MacDonald, R. D. Baltezore, W. J. Parks. Assignee: Motorola Inc. In a phase modulating system in which a carrier wave is modulated by a modulating wave, a system for compressing the modulating wave.

2,759,104 Multivibrator Oscillator Generator—A. M. Skellet. Assignee: National Union Electric Corporation. An oscillator generator employing a pair of transistors with associated cross connections and feedback circuits whereby both sinusoidal and square topped waves are simultaneously obtainable.

2,759,111 Transistor Trigger Circuit—R. Wideroe. Assignee: Aktiengesellschaft Brown, Boverie & Cie (A Swiss Company). In a control circuit: a transistor with control, collector and base electrodes, a first and second circuits combined with said transistor, means for promoting feedback from the second circuit to the first circuit, an input circuit including two asymmetrically conducting devices.

(To be continued)

MARKET NEWS . . .

Price Reductions

General Electric has again reduced prices on its lines of silicon controlled rectifiers. The latest price reductions range from 25% on the 16-ampere, 200-V model, to 14% on the 10-ampere, 300-V model. All voltage models in both the 10-ampere and 16-ampere lines are affected by the latest price revision. The new prices are effective July 1.

Transitron Electronic Corporation of Wakefield, Massachusetts, announces a major price reduction on its 2N1139 fast silicon logic transistor with 150 mc cutoff. The nearly 50% price reduction reflects decreases manufacturing costs due to recent large quantity orders. Transistron reports immediate availability from distributors stocks or local company field offices.

Motorola Semiconductors has reduced prices on its silicon Zener diode line from 10% to 40% according to an announcement from Dr. C. L. Hogan, General Manager. Information on these new diode prices may be obtained by writing Motorola, Inc., Semiconductor Products Division, Dept. NZP, 5005 E. McDowell Rd., Phoenix Arizona.

Merger of Victoreen Instrument Company, electronic device manufacturer and Tenney Engineering Inc., manufacturer of environmental test chambers was voted subject to stockholder approval.

The semiconductor device production of Nippon Electric Co., Ltd., Japan, is now roughly 500,000 transistors and 600,000 diodes per month. The company plans to triple its monthly production this year. According to the Wall Street Journal, the shipment of Japanese transistors into this country is still quite small. In the first three months of this year the transistors imported from Japan totaled 42,000; a sharp gain from 16,000 in the like period in 1958. Last year Japan shipped 11,000 here. U.S. makers of transistors produced 47 million units last year. This year they expect to produce 80 million units.

The Office of Defense Research and Engineering of the Advisory Group on Electronic Defense Department, has prepared a summary of more than 380 research and development programs for electronic tubes and semiconductor devices that have been conducted for the last two years. Of these, 155 projects were in the semiconductor device section. Approximately $18 million was made available during the past fiscal year, which ended June 30th, for research on tubes and semiconductor devices.

An underwriting group headed by Kidder, Peabody & Co. recently offered to the public 95,000 shares of $1 par value common stock of Polarad Electronics Corporation at a price of $19 per share. An additional 5,000 shares have been offered to employees. Net sales in the nine months ended March 31, 1959 were $8,666,000 and net income applicable to common stock was $310,000, compared with $6,345,000 and $206,000, respectively, in the similar period ended a year earlier. About 61 per cent of sales in the latest period were pursuant to government defense contracts and subcontracts, and approximately 32 per cent were to industrial purchasers and government laboratories engaged in defense work.

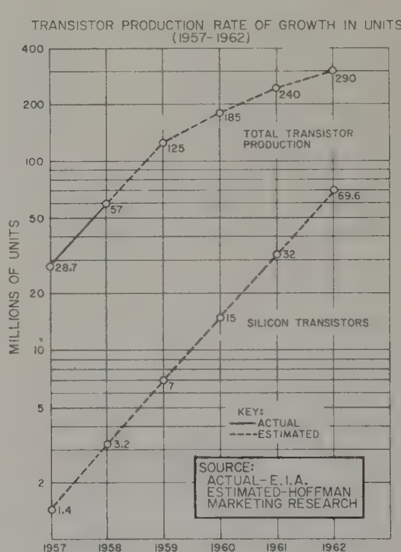
Daystrom Incorporated reports that sales were slightly below the previous year and earnings were substantially lower. For fiscal 1959, net sales were $76,640,000, compared with $81,714,000 for the previous fiscal year. Net earnings amounted to $1,207,000 or $1.32 a share before special charge of $643,000 after taxes equal to 70 cents a share. The charge represented a write-off of inventory no longer needed by the *Weston Instruments Division*. Net earnings after the special charge amounted to 62 cents a share.

Directors of the company have declared the regular quarterly dividend of 30¢ a share on the common stock. The dividend is payable August 14, 1959 to stockholders of record July 27, 1959.

General Instrument Corporation, for the fiscal year ended February 28, 1959, topped all previous 36-year sales records, doubled pre-tax profits and increased per share earnings 26%. The company reports a volume of $46,562,300 for the year (of which 42% was in military-industrial electronics) an increase of 19% over the previous year's sales of $39,195,749.

Board Chairman Martin H. Benedek recently advised shareholders at the annual meeting in Newark, that for the first fiscal quarter (ended May 31, 1959), sales "should be at least $12.5 million and will unquestionably top all previous records for the period." Last year's first quarter sales were $8,679,027. Semi-conductor shipments for the first quarter, are estimated to be three times those of last year's first quarter and current semi-conductor backlog is almost triple last year's at this time.

James T. Parry, marketing research manager for Hoffman Electronics Corp., predicted in a report based on a market survey that silicon transistors, which accounted for only 5 per cent of all transistors sold in 1957, will represent about 24 per cent of total sales in 1962. The results of this survey are shown in the graph below. Sales of silicon types



in 1957 amounted to 1.44 million units, about 5 per cent of the 28.7 million transistors sold, while dollar volume of silicon transistors for the year represented 30 per cent of the total, due to the higher unit cost of this type. Total dollar volume of silicon types in 1957 was estimated at $21.5 million.

Stockholders of Hazeltine Corporation, recently voted to split the Company's common stock two-for-one and to increase the authorized number of no-par value common stock from 1,500,000 to 3,000,000 shares.

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN APR. 1, 1959 and MAY 31, 1959 ONLY.
Charts of Silicon Zener of Avalanche Diodes, Switching Diodes, and other types of diodes will be published in the SEPTEMBER issue of SCP.

MANUFACTURERS

AMP— Amperex Electronic Corp.
AUD— Audio Devices, Inc.
BEN— Bendix Aviation Corp.
BER— Berkshire Labs
BOG— Bogue Electric Mfg. Co.
BOM— Bomac Labs
BRA— Bradley Labs
BTHB— British Thomson-Houston Export Co., Ltd.
CBS— CBS Electronics
CDC— Continental Device Corp.
COL— Columbus Electronics Corp.
CTP— Clevite Transistor Products, Inc.
CSF— Compagnie Generale de T.S.F.
EEVB— English Electric Valve Co., Ltd.
ERI— Erie Resistor Corp.
FAN— Fansteel Metallurgical Corp.
FERB— Ferranti Ltd.
GAH— Gahagan, Inc.
GECB— General Electric Co., Ltd.
GE— General Electric Company, Semiconductor Div.
GIC— General Instrument Corp.
GTC— General Transistor Corp.
HSD— Hoffman Semiconductor Division
HUG— Hughes Products Division
IFHS— Institutet for Halvedarforskning
INRC— International Rectifier Corp.
IRC— International Resistance Co.
ITT— International Tel. & Tel. Corp.
KEM— Kemtron Electron Products, Inc.
LCTF— Laboratoire Central de Telecommunications
MAL— P. R. Mallory & Co., Inc.
MIC— Microwave Associates, Inc.
MOT— Motorola, Inc.
MUL— Mullard, Ltd.
NAE— North American Electronics
NPC— Nucleonic Products Co., Inc.
OHM— Ohmite Manufacturing Co.
PHI— Philco Corp. Lansdale Tube Company
PSI— Pacific Semiconductors, Inc.
QSC— Qutronic Semiconductor Corp.
RAY— Raytheon Company
RCA— Radio Corporation of America, Semiconductor D
SAR— Sarkes Tarzian, Inc., Rectifier Division
SCN— Semicon, Inc.
SEM— Semi-Elements Inc.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SSD— Sperry Semiconductor Division
SSP— Solid State Products, Inc.
STC— Shockley Transistor Corp.
STCB— Standard Telephone & Cables, Ltd.
SYL— Sylvania Electric Products, Inc.
SYN— Syntron Co.
TEX— Texas Research Assoc.
TFKG— Telefunken, Ltd.
THE— Thermosen, Inc.
TI— Texas Instruments, Inc.
TKD— Tekade, Nurnberg, Germany
TOK— Tokyo Tsushin Kogyo, Ltd.
TRA— Transitron Electronic Corp.
TUN— Tung-Sol Electric, Inc.
TSC— Trans-Sil Corp.
USD— United States Dynamics Corp.
USS— U. S. Semiconductor Products, Inc.
VIC— Vickers Inc.
WEC— Western Electric Co.
WEST— Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered diodes and rectifiers.

Compagnie Generale de T.S.F.: 1N127, 1N191, 1N192, 1N198
Continental Device: 1N702 thru 1N720, 1N761 thru 1N768
Hughes: 1N643, 1N658 thru 1N663, 1N702 thru 1N720
Pacific Semiconductors: 1N702 thru 1N725, 1N746 thru 1N759, 1N789 thru 1N804
Philco: 1N26, 1N26M, 1N26A, 1N26AM, 1N26B, 1N26BM, 1N78, 1N78M, 1N78A, 1N78AM, 1N78B, 1N78BM, 1N78C, 1N78CM, 1N1838
RCA: 1N440B thru 1N445B, 1N536 thru 1N540, 1N547, 1N1095
U.S. Dynamics: 1N248, 1N249, 1N250, 1N1124 thru 1N1128, 1N1199 thru 1N1206, 1N1341 thru 1N1348
U.S. Semiconductor Products: 1N253, 1N254, 1N255, 1N256

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
1N846	2	Si	50				.20	25	.60	20	35	25	HUG
1N847	2	Si	100				.20	25	.60	20	70	25	HUG
1N848	2	Si	200				.20	25	.60	20	140	25	HUG
1N849	2	Si	300				.20	25	.60	20	210	25	HUG
1N850	2	Si	400				.20	25	.60	20	280	25	HUG
1N851	2	Si	500				.20	25	.60	20	350	25	HUG
1N852	2	Si	600				.20	25	.60	20	420	25	HUG
1N853	2	Si	700				.20	25	.60	20	490	25	HUG
1N854	2	Si	800				.20	25	.60	20	560	25	HUG
1N855	2	Si	900				.20	25	.60	20	630	25	HUG
1N856	2	Si	1000				.20	25	.60	20	700	25	HUG
1N857	2	Si	50				150	25	.60	20	35	25	HUG
1N858	2	Si	100				150	25	.60	20	70	25	HUG
1N859	2	Si	200				150	25	.60	20	140	25	HUG
1N860	2	Si	300				150	25	.60	20	210	25	HUG
1N861	2	Si	400				150	25	.60	20	280	25	HUG
1N862	2	Si	500				150	25	.60	20	350	25	HUG
1N863	2	Si	600				150	25	.60	20	420	25	HUG
1N864	2	Si	700				150	25	.60	20	490	25	HUG
1N865	2	Si	800				150	25	.60	20	560	25	HUG
1N866	2	Si	900				150	25	.60	20	630	25	HUG
1N867	2	Si	1000				150	25	.60	20	700	25	HUG
1N868	2	Si	50				100	25	.60	20	35	25	HUG
1N869	2	Si	100				100	25	.60	20	70	25	HUG
1N870	2	Si	200				100	25	.60	20	140	25	HUG

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier
Ø Insulated Base
5. Controlled Rectifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

Ø Dynamic

Under Mfr.

6. Available in stock form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ —Inlet Temperature of Coolant

Type No.

† —Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

Under E_f

Ø - at 125°C

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C: I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current: I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
1N871	2	Si	300				100	25	.60	20	210	25	HUG
1N872	2	Si	400				100	25	.60	20	280	25	HUG
1N873	2	Si	500				100	25	.60	20	350	25	HUG
1N874	2	Si	600				100	25	.60	20	420	25	HUG
1N875	2	Si	700				100	25	.60	20	490	25	HUG
1N876	2	Si	800				100	25	.60	20	560	25	HUG
1N877	2	Si	900				100	25	.60	20	630	25	HUG
1N878	2	Si	1000				100	25	.60	20	700	25	HUG
1N879	2	Si	50				50	25	.60	20	35	25	HUG
1N880	2	Si	100				50	25	.60	20	70	25	HUG
1N881	2	Si	200				50	25	.60	20	140	25	HUG
1N882	2	Si	300				50	25	.60	20	210	25	HUG
1N883	2	Si	400				50	25	.60	20	280	25	HUG
1N884	2	Si	500				50	25	.60	20	350	25	HUG
1N885	2	Si	600				50	25	.60	20	420	25	HUG
1N886	2	Si	700				50	25	.60	20	490	25	HUG
1N887	2	Si	800				50	25	.60	20	560	25	HUG
1N888	2	Si	900				50	25	.60	20	630	25	HUG
1N889	2	Si	1000				50	25	.60	20	700	25	HUG
1N1183	2	Si	50	40			35	140	.60	20ma	50	25J	WEST-6
1N1184	2	Si	100	80			35	140	.60	20ma	100	25J	WEST-6
1N1185	2	Si	150	120			35	140	.60	20ma	150	25J	WEST-6
1N1186	2	Si	200	160			35	140	.60	20ma	200	25J	WEST-6
1N1187	2	Si	300	240			35	140	.60	20ma	300	25J	WEST-6
1N1188	2	Si	400	320			35	140	.60	20ma	400	25J	WEST-6
1N1189	2	Si	500	400			35	140	.60	20ma	500	25J	WEST-6
1N1190	2	Si	600	480			35	140	.60	20ma	600	25J	WEST-6
1N1581	2	Si	50				3.0	150C	1.5	500		150	USD
1N1582	2	Si	100				3.0	150C	1.5	500		150	USD
1N1583	2	Si	200				3.0	150C	1.5	500		150	USD
1N1584	2	Si	300				3.0	150C	1.5	500		150	USD
1N1585	2	Si	400				3.0	150C	1.5	500		150	USD
1N1586	2	Si	500				3.0	150C	1.5	500		150	USD
1N1587	2	Si	600				3.0	150C	1.5	500		150	USD
1N2128	2	Si	50				20	125C	.50	10ma		130C	INRC
1N2129	2	Si	100				20	125C	.50	10ma		130C	INRC
1N2130	2	Si	150				20	125C	.50	10ma		130C	INRC
1N2131	2	Si	200				20	125C	.50	10ma		130C	INRC
1N2132	2	Si	250				20	125C	.50	10ma		130C	INRC
1N2133	2	Si	300				20	125C	.50	10ma		130C	INRC
1N2134	2	Si	350				20	125C	.50	10ma		130C	INRC
1N2135	2	Si	400				20	125C	.50	10ma		130C	INRC
1N2136	2	Si	450				20	125C	.50	10ma		130C	INRC
1N2137	2	Si	500				20	125C	.50	10ma		130C	INRC
1N2176	2	Si	50				1.0	150C	1.1	300		150	USD
1N2177	2	Si	100				1.0	150C	1.1	300		150	USD
1N2178	2	Si	150				1.0	150C	1.1	300		150	USD
1N2179	2	Si	200				1.0	150C	1.1	300		150	USD
1N2180	2	Si	300				1.0	150C	1.1	300		150	USD
1N2181	2	Si	400				1.0	150C	1.1	300		150	USD
1N2182	2	Si	500				1.0	150C	1.1	300		150	USD
1N2183	2	Si	600				1.0	150C	1.1	300		150	USD
1N2184	2	Si	50				3.0	150C	1.5	5000		150	USD
1N2185	2	Si	100				3.0	150C	1.5	5000		150	USD
1N2186	2	Si	150				3.0	150C	1.5	5000		150	USD
1N2187	2	Si	200				3.0	150C	1.5	5000		150	USD
1N2188	2	Si	300				3.0	150C	1.5	5000		150	USD
1N2189	2	Si	400				3.0	150C	1.5	5000		150	USD
1N2190	2	Si	500				3.0	150C	1.5	5000		150	USD
1N2191	2	Si	600				3.0	150C	1.5	5000		150	USD
1N2194	2	Si	50				6.0	150C	1.25	5000		150	USD
1N2195	2	Si	100				6.0	150C	1.25	5000		150	USD
1N2196	2	Si	150				6.0	150C	1.25	5000		150	USD
1N2197	2	Si	200				6.0	150C	1.25	5000		150	USD
1N2198	2	Si	300				6.0	150C	1.25	5000		150	USD
1N2199	2	Si	400				6.0	150C	1.25	5000		150	USD
1N2200	2	Si	500				6.0	150C	1.25	5000		150	USD
1N2201	2	Si	600				6.0	150C	1.25	5000		150	USD
1N2204	2	Si	50				12	150C	1.25	5000		150	USD
1N2205	2	Si	100				12	150C	1.25	5000		150	USD
1N2206	2	Si	150				12	150C	1.25	5000		150	USD
1N2207	2	Si	200				12	150C	1.25	5000		150	USD
1N2208	2	Si	300				12	150C	1.25	5000		150	USD
1N2209	2	Si	400				12	150C	1.25	5000		150	USD
1N2210	2	Si	500				12	150C	1.25	5000		150	USD

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
1N2211	2	Si	600				12	150C	1.25	5000		150	USD
1N2348	2	Si	50				1.0	150C	1.1	300		150	USD
1N2349	2	Si	100				1.0	150C	1.1	300		150	USD
1N2350	2	Si	150				1.0	150C	1.1	300		150	USD
1N2357	1,2,3	Si	1400	1400	400	2.0	.40	25		1.0	1400	25	COL
1N2358	1,2,3	Si	1500	1500	400	2.0	.40	25		1.0	1500	25	COL
1N2359	1,2,3	Si	1600	1600	400	2.0	.40	25		1.0	1600	25	COL
1N2360	1,2,3	Si	1800	1800	400	2.0	.40	25		1.0	1800	25	COL
1N2361	1,2,3	Si	2000	2000	400	2.0	.40	25		1.0	2000	25	COL
1N2362	1,2,3	Si	1400	1400	1000	2.0	1.0	25		1.0	1400	25	COL
1N2362A	1,2,3	Si	1400	1400	5000	2.0	5.0	25		1.0	1400	25	COL
1N2362B	1,2,3	Si	1400	1400	10A	2.0	10	25		1.0	1400	25	COL
1N2364	1,2,3	Si	1500	1500	1000	2.0	1.0	25		1.0	1500	25	COL
1N2364A	1,2,3	Si	1500	1500	5000	2.0	5.0	25		1.0	1500	25	COL
1N2364B	1,2,3	Si	1500	1500	10A	2.0	10	25		1.0	1500	25	COL
1N2366	1,2,3	Si	1600	1600	1000	2.0	1.0	25		1.0	1600	25	COL
1N2366A	1,2,3	Si	1600	1600	5000	2.0	5.0	25		1.0	1600	25	COL
1N2366B	1,2,3	Si	1600	1600	10A	2.0	10	25		1.0	1600	25	COL
1N2368	1,2,3	Si	1800	1800	1000	2.0	1.0	25		1.0	1800	25	COL
1N2368A	1,2,3	Si	1800	1800	5000	2.0	5.0	25		1.0	1800	25	COL
1N2368B	1,2,3	Si	1800	1800	10A	2.0	10	25		1.0	1800	25	COL
1N2370	1,2,3	Si	2000	2000	1000	2.0	1.0	25		1.0	2000	25	COL
1N2370A	1,2,3	Si	2000	2000	5000	2.0	5.0	25		1.0	2000	25	COL
1N2370B	1,2,3	Si	2000	2000	10A	2.0	10	25		1.0	2000	25	COL
1N2382	1	Si	4000	4000			.15	25	18	100	4000	100	PSI
1N2383	1	Si	6000	6000			.10	25	27	100	6000	100	PSI
1N2384	1	Si	8000	8000			.07	25	27	100	8000	100	PSI
1N2385	1	Si	10K	10K			.07	25	39	100	10K	100	PSI
1T22G	1	Ge	75	60	5.0	1.0	.05	25		500	50	25	SONY
1T23G	1	Ge	30	20	2.5	1.0	.025	25		50	10	25	SONY
1T2011	2	Si	100	100			.75	25		300	100	150	SONY
1T2012	2	Si	200	200			.75	25		300	200	150	SONY
1T2013	2	Si	300	300			.75	25		300	300	150	SONY
1T2014	2	Si	400	400			.75	25		300	400	150	SONY
1T2015	2	Si	500	500			.75	25		300	500	150	SONY
1T2016	2	Si	600	600			.75	25		300	600	150	SONY
302E	2	Si	250	200			35	140	.60	20ma	250	25J	WEST-6
302G		Si	350	280			35	140	.60	20ma	350	25J	WEST-6

Shown below (AA10 to CA60) is the corrected information incorrectly shown in the June 1959 issue of SCP.

TYPE NO.	USE	MAT	PIV	MAX. CONT. WORK. VOLT.	I_f	E_f	MAX. D.C. OUTPUT CURRENT	T	MAX. FULL LOAD VOLT. DROP	I_b	E_b	T	MFR.
AA10	2⍁	Si	100	100	2A	1.0	2.0	135C	.50	10	100	25	VIC
AA20	2⍁	Si	200	200	2A	1.0	2.0	135C	.50	10	200	25	VIC
AA30	2⍁	Si	300	300	2A	1.0	2.0	135C	.50	10	300	25	VIC
AA40	2⍁	Si	400	400	2A	1.0	2.0	135C	.50	10	400	25	VIC
AA50	2⍁	Si	500	500	2A	1.0	2.0	135C	.50	10	500	25	VIC
AA60	2⍁	Si	600	600	2A	1.0	2.0	135C	.50	10	600	25	VIC
BA10	2⍁	Si	100	100	8A	1.0	8.0	135C	.50	10	100	25	VIC
BA20	2⍁	Si	200	200	8A	1.0	8.0	135C	.50	10	200	25	VIC
BA30	2⍁	Si	300	300	8A	1.0	8.0	135C	.50	10	300	25	VIC
BA40	2⍁	Si	400	400	8A	1.0	8.0	135C	.50	10	400	25	VIC
BA50	2⍁	Si	500	500	8A	1.0	8.0	135C	.50	10	500	25	VIC
BA60	2⍁	Si	600	600	8A	1.0	8.0	135C	.50	10	600	25	VIC
CA10	2⍁	Si	100	100	12A	1.0	12	135C	.50	10	100	25	VIC
CA20	2⍁	Si	200	200	12A	1.0	12	135C	.50	10	200	25	VIC
CA30	2⍁	Si	300	300	12A	1.0	12	135C	.50	10	300	25	VIC
CA40	2⍁	Si	400	400	12A	1.0	12	135C	.50	10	400	25	VIC
CA50	2⍁	Si	500	500	12A	1.0	12	135C	.50	10	500	25	VIC
CA60	2⍁	Si	600	600	12A	1.0	12	135C	.50	10	600	25	VIC
CD1116	1	Si	300		250	1.0				10	300	150	CDC
CD1117	*	Si	10		1.0	.58-.70				.10	5.0	25	CDC
*Voltage reference(forward)					100	1.0							

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Ø Insulated Base

5. Controlled Rectifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

⍁ Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ — Inlet Temperature of Coolant

Type No.

† — Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

Under E_f

⍁ - at 125°C

TYPE NO.	USE (See Code Below)	MAT	PIV	MAX. CONT. WORK. VOLT.	Min. Forward Current @ 25°C		MAX. D.C. OUTPUT CURRENT[4] @	T (°C)	MAX. FULL LOAD VOLT. DROP[4]	Max. Rev. Current			MFR. (See code at start of charts)
					I_f @	E_f				I_b @	E_b @	T	
			(volts)	(volts)	(mA)	(volts)	(amps)		(volts)	(uA)	(volts)	(°C)	
CH103A	2	Si	100	100			20	150		5000	100	150	TUN
CH103B	2	Si	200	200			20	150		5000	200	150	TUN
CH103C	2	Si	300	300			20	150		5000	300	150	TUN
CH103D	2	Si	400	400			20	150		5000	400	150	TUN
CH103E	2	Si	500	500			20	150		5000	500	150	TUN
CH103F	2	Si	600	600			20	150		5000	600	150	TUN
CH103Z	2	Si	50	50			20	150		5000	50	150	TUN
CH104A	2	Si	100	100			35	150		10000	100	150	TUN
CH104B	2	Si	200	200			35	150		10000	200	150	TUN
CH104C	2	Si	300	300			35	150		10000	300	150	TUN
CH104D	2	Si	400	400			35	150		10000	400	150	TUN
CH104E	2	Si	500	500			35	150		10000	500	150	TUN
CH104F	2	Si	600	600			35	150		10000	600	150	TUN
CH104Z	2	Si	50	50			35	150		10000	50	150	TUN
OY2	1,2	Ge	250	100	400	1.0	.20	45A	.40	250	250	25	TKD
OY3	1,2	Ge	200	100	400	1.0	.20	45A	.40	250	200	25	TKD
OY4	1,2	Ge	150	100	400	1.0	.20	45A	.40	250	150	25	TKD
OY5	1,2	Ge	100	100	400	1.0	.20	45A	.40	250	100	25	TKD
SFD106	1	Ge		25	5.0	1.0				600	25	25	CSF
SFD108	1	Ge		115	10	1.5				250	100	25	CSF
SFD110	1	Ge		45	10	2.2				350	45	25	CSF
SFR105/1	2	Ge		100			4.0	25	.70	15ma	100	75	CSF
SFR105/2	2	Ge		100			6.5	25	.70	15ma	100	75	CSF
SFR106	2	Ge		50			1.2	25	.70	15ma	50	75	CSF
SFR106/1	2	Ge		50			5.0	25	.70	15ma	50	75	CSF
SFR106/2	2	Ge		50			7.0	25	.70	15ma	50	75	CSF
STC101	1	Si	50	35	10	.7-.74	.20			15	35	150	SIL
STC102	1	Si	50	35	10	.7-.74	.20			5.0	35	150	SIL
STC103	1	Si	80	70	10	.7-.74	.20			15	70	150	SIL
STC104	1	Si	80	70	10	.7-.74	.20			5.0	70	150	SIL
STC105	1	Si	150	130	10	.7-.74	.20			15	130	150	SIL
STC106	1	Si	150	130	10	.7-.74	.20			5.0	130	150	SIL
STC107	1	Si	200	180	10	.7-.74	.20			15	180	150	SIL
STC108	1	Si	200	180	10	.7-.74	.20			5.0	180	150	SIL

VOLTAGE VARIABLE CAPACITOR DIODES

TYPE NO.	CAPACITANCE C @ Eb		PIV	Q @ FREQ.		MFR.
	(uuf)	(volts)		Min. Q	(mc)	
MA460F	1.0max.	6.0	6.0	7.0	10000	MIC
MA460G	1.0max.	6.0	6.0	8.0	10000	MIC
MA460H	1.0max.	6.0	6.0	9.0	10000	MIC
SC1	10	4.0	22	35⍁	50	TRA
SC2	20	4.0	22	35⍁	50	TRA
SC3	35	4.0	18	35⍁	50	TRA
SC5	50	4.0	11	35⍁	50	TRA
SC7	70	4.0	9.0	35⍁	50	TRA
SC11	105	4.0	6.0	35⍁	50	TRA
SC15	150	4.0	6.0	35⍁	50	TRA
SCH51	.50	4.0	10	40	100	TRA
SCH51/A Ø	.50	4.0	10	40	100	TRA
SCH52	1.0	4.0	7.0	40	100	TRA
SCH52/A Ø	1.0	4.0	7.0	40	100	TRA
D1114	.70 - 1.4	.60 - 20	30	20	100	SYL
D1156	.70 - 2.0	.60 - 20	30	30	100	SYL
ZC10A	30 ± 3.0	1.0	6.0	35	50	FERB
ZC10B	30 ± 6.0	1.0	6.0	35	50	FERB

Under Type No.
Ø - Ceramic Microwave Crystal Cartridge

Under Q
⍁ - Typical

PERSONNEL NOTES

The election of Dr. Herbert Trotter, Jr. as a Senior Vice President of Sylvania Electric Products Inc. was announced by President Robert E. Lewis. Dr. Trotter, a physicist, has been designated Senior Vice President, Engineering and Research, with over-all responsibility for the engineering program as it relates to the entire scope of Sylvania's activities, and for the operations of Sylvania Research Laboratories, a major division of the company. His headquarters will be at Sylvania's executive offices in New York City.

Dr. Paul N. Russell has joined the research staff of Hoffman Electronics Corporation's new Science Center in Santa Barbara, Calif., as a senior scientist, Dr. Lloyd T. DeVore, vice president and director, announced. He will be concerned with research in semiconductor materials, magnetics and dielectrics. Dr. Russell received his Ph.D. from the University of Missouri, Columbia, Mo., where he specialized in solid state physics. He is presently secretary of the electronics division of the American Ceramic Society and a member of the American Physical Society.

Wellington Vandeveer will take over the post of president, it was announced by the Circo Equipment Company, Clark, New Jersey, manufacturers of metal degreasing and washing equipment. He succeeds Melville Morris, who has resigned from the company. At the same time, Severn Carlson was named to direct sales activities for both Circo Equipment and the newly formed subsidiary, Circo Ultrasonic Corporation. Circo also announced the appointment of Benson Carlin as Executive Vice-President of the subsidiary. Mr. Carlin is a national authority in the ultrasonics field.

Alvin B. Phillips has been appointed Chief Engineer of Motorola's Mesa transistor product line according to an announcement from Motorola's Semiconductor Products Division in Phoenix, Arizona. In this new position, Mr. Phillips will be in charge of engineering design and development of germanium and silicon Mesa transistors for high frequency switching, amplifier and power applications.

The following appointments to positions in Hoffman Electronics Corporation's West Coast semiconductor plant, now under construction in El Monte, Calif., were announced by Maurice E. Paradise, executive vice president of the Semiconductor Division: Howard Mann, previously superintendent of manufacturing for the Semiconductor Division, Hughes Aircraft Co., was named production manager. Irwin Rubin, formerly chief solar production engineer for the Hoffman Semiconductor Division's Evanston, Ill., plant, chief manufacturing engineer. Emory Glancy, former superintendent of maintenance for International Rectifier Corporation, plant engineer.

The appointment of Harry R. Marty as manager of its new Owensboro plant was announced by the W. R. Grace & Co., Dewey and Almy Chemical Division, Cambridge, Massachusetts. He succeeded James F. Murphy, Jr., chief engineer, on July 1, at which time Mr. Murphy returned to Cambridge. He received a B.S. in Chemical Engineering from the University of Missouri in 1943. A registered professional engineer in Massachusetts, he is a member of the American Institute of Chemical Engineers, the American Chemical Society, and Alpha Chi Sigma.

Dr. Herbert M. Hershenson has joined Baird-Atomic, Inc. as assistant technical director, product planning. Dr. Hershenson will work with members of the Baird-Atomic engineering staff on development of new instruments to meet specific market needs and on applications of the firm's atomic and chemical analysis equipment. Dr. Hershenson holds an S.B. degree in chemistry and a Ph.D. degree in analytical chemistry from Massachusetts Institute of Technology. He is a member of American Chemical Society, American Association for the Advancement of Science and Sigma Xi.

Dr. Charles D. Bradley, president of Bradley Semiconductor Corporation, manufacturer of rectifiers and other electronic components, 275 Welton Street, New Haven, Connecticut, has announced the appointment of William J. Gagnon as vice president. Mr. Gagnon has been general sales manager of the firm since he joined it in 1954. He is a member of the Institute of Radio Engineers, served as chairman of the instrument rectifiers committee of the American Institute of Electrical Engineers, and belongs to the New Haven Chamber of Commerce Speakers Guild.

Appointment of Maurice Friedman as Vice President and General Manager of the General Instrument Semiconductor Division, with plant and headquarters at Newark, N. J., is announced by General Instrument Corporation Board Chairman Martin H. Benedek. Mr. Friedman, a specialist in semiconductor design and engineering, has headed the division since its formation in 1955. A graduate of New York University, he is a member of the American Chemical Society and the Electrochemical Society.

Carl L. Smith has been appointed Plant Manager of the Boone, North Carolina plant of International Resistance Company, electronic component manufacturer. Announcement was made by F. P. Rice, IRC Director of Operations. In this capacity Mr. Smith is responsible for the manufacture of rectifiers and semiconductor diodes, power resistors, and special-application fuse resistors.

Dr. F. Kenneth Brasted, former President of the University of Dallas, has joined Texas Instruments Incorporated as Administrative Director of the Central Research Laboratory. He reports directly to Dr. Gordon K. Teal, Assistant Vice President in charge of the Central Research Laboratory. His responsibilities will include budgeting and control, engineering services, technical information services, and other administrative functions of TI's central research organization. He succeeds William Love who has transferred to TI's Central Staff Personnel division for special assignment.

Robert A. Jewett has joined Semimetals, Inc., Richmond Hill, Long Island, as vice president of marketing, it is announced by Morton D. Brozinsky, company president. In his new post, Mr. Jewett will coordinate and direct the sales and marketing of semiconductor materials. Mr. Jewett. who is well known in the industry, was previously sales manager with the Chemical and Metallurgical Division of Sylvania Electric. Prior to his transfer to that division in 1952, he worked in Sylvania's Engineering Laboratories in New York. He received his education at the Polytechnic Institute of Brooklyn.

G. Edward Pavlik has been named to the product planning staff of Motorola, Inc., Semiconductor Products Division, according to an announcement from T. D. Hinkleman, Manager of Product Planning. In his new position, Mr. Pavlik will be product planner for the Motorola Mesa and Motorola Switching transistor product lines. He was a standards engineer on transistors with the Radio Corporation of America prior to joining Motorola Semiconductors. Mr. Pavlik received a B.S. Degree in Engineering Physics from the University of Michigan in 1956.

The promotion of Francis X. Urrico as section head in charge of the electronic equipment development department of the Semiconductor Division of Sylvania Electric Products Inc., has been announced by Theodore R. Bunnell, division manufacturing services manager. Mr. Urrico has been a senior engineer in the department since 1957. He joined Sylvania as an electronic design engineer at division headquarters in Woburn, Mass., in 1956. Prior to that Mr. Urrico was with the Naval Research Laboratory in Washington, D. C., and with the U. S. Army, at the Electronic Proving Ground in Ft. Huachuca, Arizona.

Dr. Michael Waldner, a physicist experienced in semiconductor electronics, has joined the device research department of Hughes Aircraft Company's Products Group as a member of the technical staff, it was announced recently. Dr. Waldner, formerly with General Electric Co., is a bachelor of science graduate of Washington University and received his master's and doctor's degrees from Cornell University.

Appointment of Edward O. Johnson as Manager, Advanced Development, RCA Semiconductor and Materials Division, was announced by D. H. Wamsley, Manager Semiconductor Engineering. Mr. Johnson will take over the position previously held by Dr. W. M. Webster who has been named Administrative Engineer on the staff of the Vice President of RCA Laboratories at Princeton, N. J. Mr. Johnson is a member of Sigma Xi, Eta Kappa Nu, and the American Physical Society, and a senior member of the Institute of Radio Engineers.

Robert A. Irvin has been named to the newly created post of manager, headquarters sales operations for Raytheon Company's Semiconductor Division. Mr. Irvin comes from Texas Instruments where he was chief sales engineer for the components division and more recently product marketing manager for germanium products. In his new post, he will assist and advise the Semiconductor Division sales manager, forecast sales, supervise the preparation of quotations, direct order processing and perform related home office sales activities.

Promotion of three engineers to senior scientists at ITT Laboratories, Nutley, N. J., has been announced. Named were Richard E. Gray, former senior project engineer of the Radio Communication Laboratory, and Henry F. Herbig and Malcolm C. Vosburgh. former executive engineers of the Wire Communication and the Avionic Systems laboratories, respectively. Their responsibilities will be the development and application of new scientific theories and laws.

George C. Messenger, expert in semiconductor device design, has joined Hughes Aircraft Company's Products Group as head of the device electronics department, it was announced by L. James Levisee, manager of the company's semiconductor division. Mr. Messenger, formerly of Philco Corp., is author of many technical papers on solid state device research. He received a bachelor of science degree in physics from Worcester Polytechnic Institute and a master's degree in electrical engineering from the University of Pennsylvania. He is a senior member of the Institute of Radio Engineers and a member of the American Physical Society.

1959 WESCON SHOW

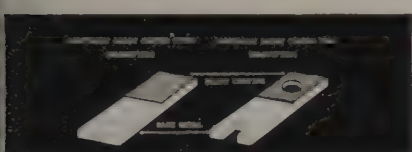
PREVIEW OF NEW PRODUCTS

The items described in this section are those which the respective manufacturers will exhibit at the Cow Palace in San Francisco, August 18-21.

Partial Coating Process

The partial coating of metals used as base tabs in the manufacture of transistors has been achieved by Alpha Metals, Inc. As a result, base metals can be coated on one side, along either edge, in the center only or overall. Typical metals and alloys that can be coated are tin, tin-antimony, tin-gallium, lead, lead-antimony, tin-lead-gold, tin-lead, silver, indium, indium-gallium. Among the materials which can be coated with these solder alloys are copper, nickel, kovar, rodar, therlo and other iron-nickel alloys.

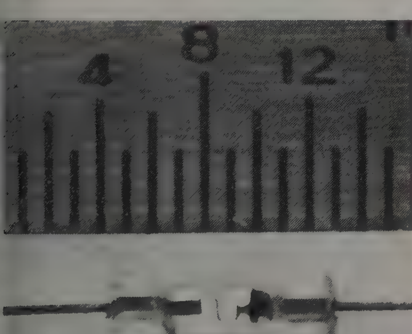
Circle 164 on Reader Service Card



All Purpose Diode

General Instrument 1N658 silicon diode offers uniform excellence in all parameters. The high conductance and fast recovery characteristics of this device, in conjunction with high breakdown voltage and extremely low reverse leakage make it ideally suited for a wide range of computer applications, as well as both general circuit and moderate power usage.

Circle 165 on Reader Service Card



Switching Transistors

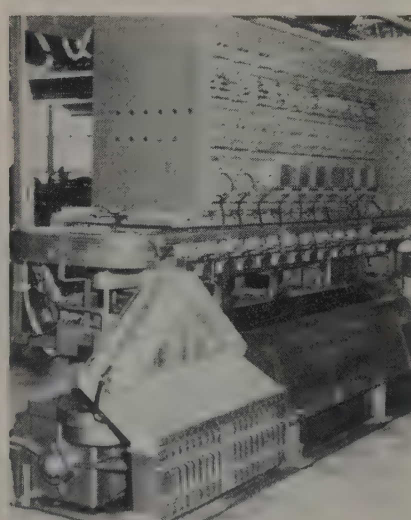
First public announcement will be made by Pacific Semiconductors, Inc. of a new line of high speed silicon switching transistors. In addition working demonstrations of the newly extended line of VHF Silicon Power transistors will be a feature of their exhibit at Booth 2801-2. Of particular engineering interest will be a developmental 30 megacycle silicon power transistor capable of delivering five watts. To dramatize its recent advances in micro-miniaturization, the company will also display circuitry revolving around the application of PSI Micro Diodes.

Circle 152 on Reader Service Card

Automatic Tester and Classifier

Panels on a recently announced high-speed machine which electronically tests and classifies semiconductor devices, such as transistors and diodes, developed by Sylvania Electric Products Inc., will highlight the company's WESCON exhibit. This Digital Automatic Tester and Classifier performs 16 separate tests and classifies semiconductors into as many as 16 categories at the rate of 1,500 units per hour and with an accuracy within the limits of 0.3 per cent. Operation of this machine is in contrast to conventional procedures in which a device may be rejected for failing to meet one set of specifications and must then undergo additional and tedious testing to determine its conformance with other specifications.

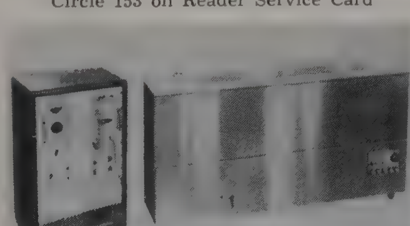
Circle 151 on Reader Service Card



Ultrasonic Equipment

Narda SonBlaster Model G-10001 Generator and NT-10004 Transducerized Tank. All stainless steel, designed for production line cleaning of printed circuit boards. Recirculation system has 2000 watt heater and thermostat regulated heat exchanger for maintaining preset solvent temperatures; solenoid controlled valves. Versetron solution level control optional. Generator input, 208/230 volt, 50/60 cycle 11.0 amps. Output is 1 kw average, 2 kw peak, 40 kc. Overall dimensions 57" long by 28" high by 11" wide. Booth 1102.

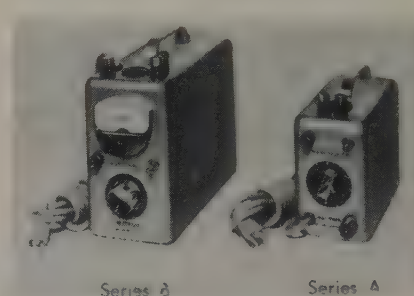
Circle 153 on Reader Service Card



Variable Power Supplies

Nutron Mfg. Co., Handivolt Series DC/AC Power Supplies. Features: High Power, Small Size, High efficiency at any voltage setting, Smooth stepless control, Low ripple DC output, Choke type filter, 2% Accuracy meter, Rated for heavy duty, Long, Service-free life, Standard outlet for AC output. Applications: General Lab use, Production Testing setups, Variable Battery, Variable Transformer, Motor Speed Control, Relay Testing, Light control, Transistor power source, Battery charging, Electroplating. Input: A Models—115V, 50-400 Cycles, B Models—115V, 50-60 Cycles.

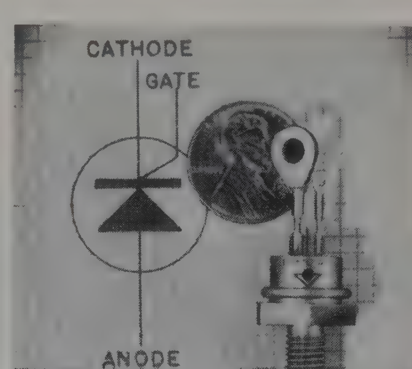
Circle 168 on Reader Service Card



Controlled Rectifier

A silicon controlled rectifier, a miniature control device combining some of the characteristics of the rectifier and the power transistor, has been announced by International Rectifier Corporation. Series X10RC *2* through X10RC *20* is rated for average currents up to 10 amperes and is available with peak inverse voltage ratings of 20, 30, 50, 70, 100, 150 and 200 volts. Leakage currents in both the forward and reverse directions are in the order of 12 ma. Forward voltage drop in the conducting state is approximately 1.5 volts at 25°C. Switching time is in the order of microseconds. All units are hermetically sealed, and have an over-all height of 1.625 inches.

Circle 156 on Reader Service Card



Silicon Rectifier Series

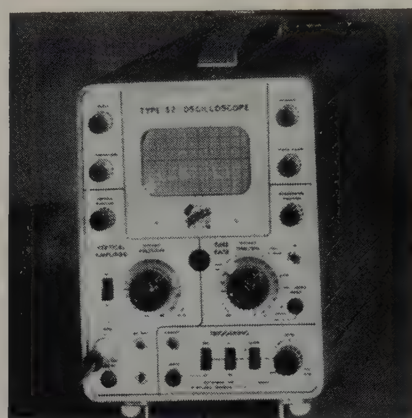
Low thermal drop (less than 10°C junction to base) and low junction temperature rise (approximately 60°C) are built-in features in the Tarzian Y series rated at 250 amperes d.c. This combination minimizes "thermal-aging" problems and extends life expectancy. Either positive or negative base polarity is available. 50 to 400 PIV. Ideally designed for use in welding, electroplating and electrolysis application, this series is also useful in any application that requires 1000 or more d.c. amperes.

Circle 161 on Reader Service Card

Portable Oscilloscope

The Tektronix Type 321 is a Transistorized Battery-Operated Portable Oscilloscope with high-performance characteristics. It will operate up to 3 hours on ten high-current (Size D) flashlight cells, up to 6 hours on rechargeable cells. It will also operate on 11 to 35 vdc, and on 110 to 125 v or 220 to 250 v, 50 to 800 cycles. It weighs only 12 pounds without batteries and measures only 5¾" x 8¼" x 16". Booth 1801-1802.

Circle 163 on Reader Service Card



Silicon References

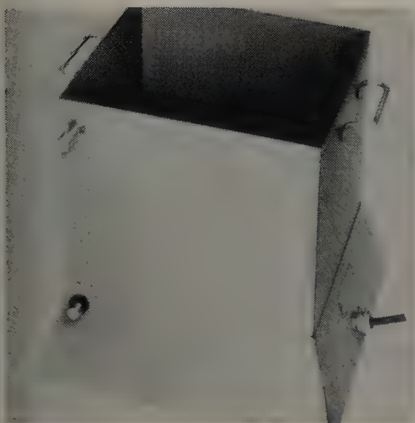
Transitron Electronic Corp., announces a new line of subminiature silicon voltage references, IN821-827 series, combining features of lower dynamic resistance and voltage stability exceeding that of a standard cell. Single-piece construction

of these devices affords ideal thermal connection between "zener" diode and the compensating stabistor, assuring that the junctions operate at the same temperature, thereby eliminating warm-up transients. Also available as symmetrical double anode types, they offer temperature coefficients as low as .001%/°C. Axial lead design and hermetically sealed glass encapsulation insure a rugged unit capable of providing long-term reliability under wide environmental extremes. Write for Bulletin TE 1352 F.

Circle 162 on Reader Service Card

Multipower Transducer

Instead of a nickel-alloy core surrounded by a coil (magnetostrictive) or polycrystalline material between two thin electrodes (piezoelectric), in the Acoustica Multipower Transducer solid metal sections are usel as integral operating elements and the active transducer material is positioned near the center of the assembly. The metal elements are machined, dimensioned, and positioned so that the overall unit has greater amplitude of motion and heat-dissipating capability. This construction minimizes the tendency of the ordinary piezoelectric



transducer to overheat at high power inputs, since the metal blocks conduct heat away from the crystal efficiently and rapidly. Elements require no cementing or other chemical bond. The use of cement and epoxy resins as integral mechanical elements has been eliminated entirely.

Circle 166 on Reader Service Card

Switching Transistors

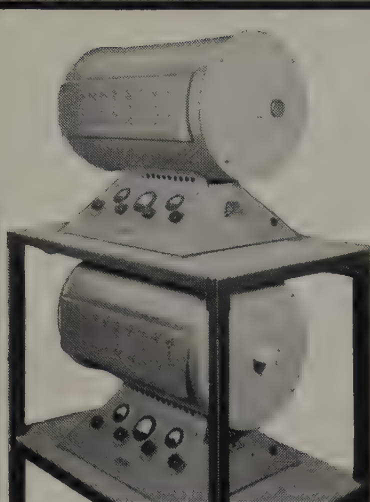
Fairchild announces the 2N706, an extremely fast silicon switching transistor optimized for saturated logic circuits operating at low current levels. The outstanding feature of this device is that it can be operated in a saturated condition with virtually no sacrifice in speed. Double diffused mesa construction gives typical DCTL propagation delay of 5 millimicroseconds per inverter. Circuit design is simplified because there is no need to use additional circuit components to keep it out of saturation. It can also be used in non-saturating circuits or as a linear amplifier. Typical maximum frequency of oscillation is 400 megacycles.

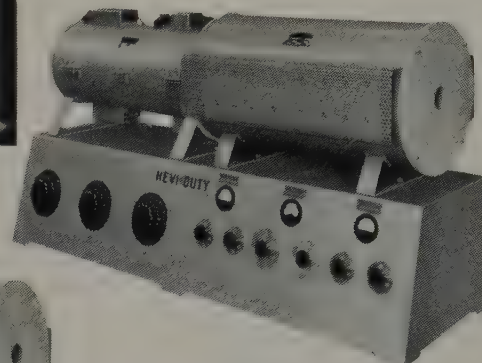
Circle 158 on Reader Service Card

Transistor Transformers

Microtran Company announces the availability of a catalog series of ultra-miniature, epoxy-molded, plug-in, printed circuit, transformers. Size is only ½" dia. x ½" high; weight 4 grams. Electrical ratings are suitable for transistor servo and audio applications. Designed to meet MIL-T-27A Grade 5, Class R, 10,000hr. reliable life. Available on special order for 125°C. operation. Tinned buss leads permit dip solder printed circuit mounting.

Circle 155 on Reader Service Card

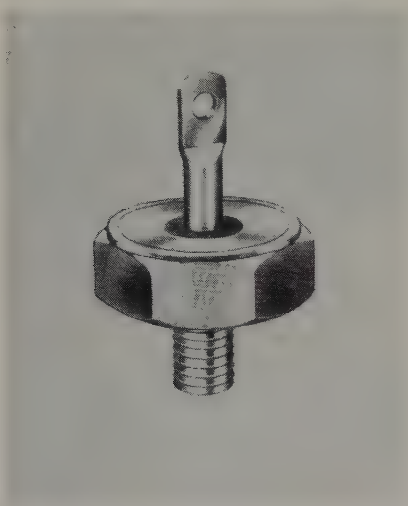




Lightweight Diodes

U. S. Semcor announces small high power, lightweight diodes which include a 25-watt zener diode. The new line comprises single diffused silicon junction zeners with voltages ranging from 7 to 100 volts and rectifiers with PIV's from 50 to 600 volts. These diodes are built with matched coefficients of expansion which prohibit separation of internal lead wire and silicon wafer, even under extreme thermal shock. They are not position-sensitive and are highly resistant to vibration. These hermetically sealed diodes have plated copper heat sink and provide excellent thermal conduction. Also available is an aluminum heat sink with weight of only 9-1/2 grams, 1/5th the usual weight; height 1.625″.

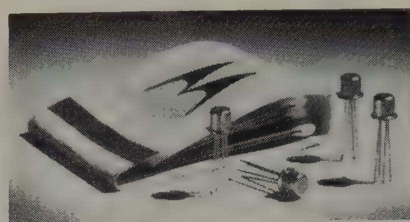
Circle 150 on Reader Service Card



Mesa Transistor Line

Motorola Semiconductors will feature its complete line of UHF Mesa transistors in Booth 3615-17. Motorola currently has the 2N695 ultra-high speed (less than 5 mu second) switching Mesa, the 2N700 UHF amplifier Mesa, and the 2N701 wide band video amplifier Mesa in volume production. The elements which are used in their fabrication have been carefully selected so that each and every Motorola Mesa can be baked out under high vacuum at 300°C before being hermetically sealed.

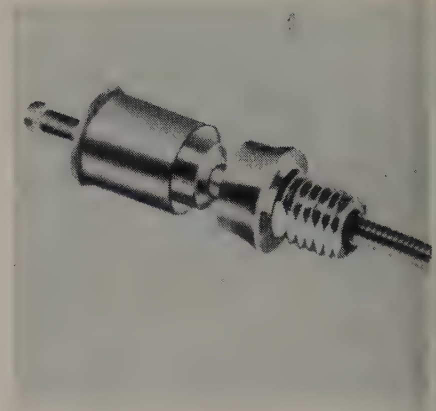
Circle 154 on Reader Service Card



Variable Trimmers

JFD Electronics Corp., announces the development of a new variable trimmer, the MAX-C, to be shown for the first time at Booth 202. The outstanding advantage of the new series is its extremely wide range of capacity per unit; approximately three times more than previous similar sized trimmers. A typical capacitor 1″ long x ⅜ DIA will have 60 Pf. range. Each model will be made available in panel mount for standard chassis circuitry, lead and lug, and 4-wire mounting types for printed circuit board applications.

Circle 157 on Reader Service Card



Switching Transistor Series

Bendix new series of nine power transistors especially designed for use in

(*Continued on page 67*)

Industry News

The Following September 1959 IRE and Jointly Sponsored Meetings Are Scheduled:

Sept 17-18	Engineering Writing & Speech Symposium, Sheraton-Plaza Hotel, Boston, & Ambassador Hotel, Los Angeles. For Information: J. M. Cryden, Litton Industries, 336 N. Foothill Rd., Beverly Hills, Calif. Alexander M. Cross, Raytheon Co., Wayland, Mass.
Sept 23-25	Special Technical Conference on Non-Linear Mag. & Mag. Amplifiers, Shoreham Hotel, Washington, D. C. For Information: F. G. Timmel, Westinghouse, Box 746, Baltimore, Md.
Sept 25-26	9th Annual Broadcast Symposium, Willard Hotel, Washington, D. C. For Information: George E. Hagerty, Westinghouse, 122 E. 42nd Street, New York City.
Sept 28-30	Nat'l Symposium on Space Elec. & Telemetry, Civic Auditorium & Whitcomb Hotel, San Francisco, Cal. For Information: George Larse, Missile Systems Div., Lockheed Aircraft Co., Sunnyvale, Calif.

Award of $150,000 contract to Texas Instruments Incorporated for study of a major semiconductor substrate device, the TI-developed ultraminiaturized semiconductor solid circuit, has been announced by the Air Research and Development Command. The semiconductor solid circuitry developed by Texas Instruments and publicly announced last March involves the creation of complete match-head-size working circuits within tiny single pieces of semiconductor material.

Columbus Electronics Corp., of Yonkers, N.Y. has announced installation of a new, internally developed automation process for its semiconductor division which is said to quadruple capacity for the firm's daily production of double diffused silicon rectifiers. Mr. Manlio Goetzl, president of Columbus, stated that the new automation machinery, equipment and procedure were developed entirely by staff engineers at the plant.

A new plant, devoted exclusively to Ultrasonics was opened on June 23rd, in Plainview, Long Island, New York, by Acoustica Associates, Inc., a leading manufacturer of ultrasonic systems for industry, national defense, hospitals, and the home.

Construction of a new manufacturing plant of Rheem Semiconductor Corporation, a subsidiary of Rheem Manufacturing Company, was begun on June 12. February 1, 1960 is the scheduled completion date.

A new three-story, 129,000 square foot addition to Motorola Semiconductor's plant in Phoenix, Arizona was formally opened Saturday, June 27. The new addition provides more than five times the production facilities for the Motorola Mesa transistor and allows room for a three fold expansion of all other current Motorola product lines.

Sylvania Electric Products Inc. has moved its executive offices and several of its corporate staff departments from 1740 Broadway to the new General Telephone Building at 730 Third Avenue, New York City.

P. R. Mallory & Co. Inc. has announced that Mallory Capacitor Company facilities for the production of solid tantalum capacitors have been moved to new Indianapolis quarters and that output has been doubled. Controlled environment in the new manufacturing area is designed to contribute to high reliability of the capacitors.

Start-up of a new plant at Owensboro, Kentucky to manufacture polyvinyl acetate polymers and copolymers, butadiene styrene synthetic rubber latices, and battery separators was announced by George W. Blackwood, President, Dewey and Almy Chemical Division, W. R. Grace & Co., Cambridge, Massachusetts.

Eastern regional offices of the Semiconductor Division, Hoffman Electronics Corporation, have been moved from Washington, D. C., to the Walter Reed Building, 710 Mattison Ave., Asbury Park, N. J.

A new $3,500,000 facility for transistor production is being rushed to completion by the Lansdale Tube Company division of Philco Corporation to meet industry demand for silicon transistors. The 65,000 square foot facility is a separate one-story brick building located behind present Lansdale Tube Company buildings on Church Road in Lansdale, Pa. Construction began in April 1959 and is expected to be completed by early September of this year.

Dean D. Knapic, President of Knapic Electro-Physics, Inc., announced the opening of a new western sales office. The new office will be under the direction of Michael G. Kaufman and will be located at 204 South Beverly Drive, Beverly Hills, California, telephone: Crestview 6-7175.

Zenith Optical Laboratories takes pleasure in announcing the opening of its' subsidiary Ultrasonic Machining Co. which was organized for the sole purpose of ultrasonic machining of extremely hard, brittle materials such as ferrites, silicon, ceramics, germanium, carbides, crystals, glass or quartz. This operation was formerly handled at the parent company in Copiague, N. Y., but is now located at 1015 Asbury Ave., Asbury Park, New Jersey.

Plans to construct a transistor plant which will eventually employ more than 2,000 persons and bring to the area an annual payroll of $7 to $8 million were announced by Charles F. Adams, president of Raytheon Company. Construction for the new plant will start early this fall and will be completed by mid-1960.

Tang Industries, Inc., 49 Jones Road, Waltham, Massachusetts, is now offering complete material services to Silicon diode and transistor manufacturers. Makes available guaranteed uniformity of Silicon single crystal quality in production quantity. Minimum dislocation density and low oxygen content are achieved. Sliced wafers are furnished to tight dimensional tolerances with or without "damaged" surfaces. Dices are supplied in round, square or rectangular shapes.

The formation, on June 16, 1959, of Bert Barron Co., offices at 15166 Ventura Blvd., Sherman Oaks, California, State 4-7800, has been announced. This new Electronic Sales Engineering Company will represent key electronic component, equipment and system manufacturers to Southern California accounts.

Wescon Preview

(from page 64)

power switching and power control circuits, such as DC-DC converters and regulated power supplies. Provided in three current gain ranges for optimum matching: 50-100, 75-150, and 100-200 at a collector current of 3 Adc. JEDEC-designated 2N1136,A,B; 2N1137,A,B; and 2N1138,A,B; they also feature extremely flat beta curve. Have 5 amp maximum current rating and can switch power up to 400 watts. Collector-emitter breakdown voltage ratings of 40, 70, and 80 eliminate burnout in high voltage applications. Booth 2708-2710.

Circle 159 on Reader Service Card

High Voltage Transistor

Raytheon 2N1275 is a medium gain, PNP, silicon fusion alloy transistor. It is primarily intended for use in high temperature, high voltage, audio, switching, and dc amplifier circuits. The 2N1275 features low saturation voltage, close parameter control throughout the rated temperature range and good current gain at collector current levels up to 50 milliamperes. Reliable hermetic sealing is assured by use of a welded package.

Circle 167 on Reader Service Card

High Voltage Rectifiers

A complete line of high voltage tiny silicon rectifiers in a reliable, subminiaturized package will be exhibited for the first time by Hughes. Available in a complete line, with 50 to 1000 volt ratings at 50 to 200 mA, these silicon rectifiers are ideally suited for design problems which combine high voltage with small size.

Circle 160 on Reader Service Card

Glass Coating

High-purity low-melting glass for coating electronic devices. Available from Baker & Adamson, General Chemical Div., Allied Chemical Corp. Ideal coating for protecting germanium and silicon transistors and diodes from atmospheric oxidation, contamination and humidity. Coating may be accomplished by dipping devices in a fluid bath of the glass, withdrawing and cooling; or through the use of a preform (compressed powder). Booth No. 1123.

Circle 169 on Reader Service Card

New Literature

A new, up-to-date, 42-page manual "Ultrasonic Liquid Level Switches," has been published and made available by Acoustica Associates, Inc., a leading manufacturer of ultrasonic systems. The manual, illustrated with drawings and diagrams, provides complete information on the Acoustica ultrasonic switches which are now being used in a wide variety of liquid level monitoring and control applications. A separate catalogue section lists available probes and control units and provides detailed specifications for each type, with clear technical drawings. The manual is a completely revised, enlarged, and up-to-date edition of an earlier booklet on the subject.

Circle 72 on Reader Service Card

Catalog #30 lists more kinds of components, as well as an increased selection in the long-established varieties of items stocked by Ohmite Mfg. Company and its distributors. Attractively illustrated and printed in two colors, this catalog is liberal with data and dimensions to facilitate ordering.

Circle 73 on Reader Service Card

New printing of a revised catalog on Syntron "Selenium Slims" high voltage cartridge-type rectifiers is announced by Syntron Company. Illustrated, 8-page booklet contains complete descriptions, data and specifications for the company's complete line of glass or phenolic tube cartridge rectifiers. Catalog also shows dimensional outlines and circuit diagrams, and explains Syntron's stack coding. Four pages contain comprehensive operational characteristics for stack sizes of five diameters (from ⅛-inch to ½-inch) with from one to 400 cells per stack. Other charts give complete information pertaining to derating for raised ambients and continuous direct current ratings.

Circle 74 on Reader Service Card

Bulletin Z-100, describing a semiconductor alloy kit, including 24 different alloys with melting points in the range of 325 F to 1100 F, a total of over 25,000 preforms, for use by semiconductor research and manufacturing engineers in developing new devices or evaluating new processes, is now available from Accurate Specialties Co. The bulletin lists the various alloys included in this kit, such as Tin, lead, Indium, Aluminum, Kovar, Aluminum-Boron, Indium-Zinc-Gallium, Tin-Antimony, Lead-silver, Lead-antimony, Indium-germanium, etc. The alloys described are in the forms of discs, washers, and spheres.

Circle 75 on Reader Service Card

A new Catalog TR-60, listing the complete industrial transformer line has been published by Triad Transformer Corporation, a division of Litton Industries. The book lists over 1000 items and contains several new lines, including micro-miniature transformers and transformers for transistor applications.

Circle 76 on Reader Service Card

A brochure describing products available from, and containing detailed information about, its new plant in Owensboro, Kentucky, is available from the W. R. Grace & Co., Dewey and Almy Chemical Division. The brochure includes a summary of products to be manufactured, including vinyl acetate polymers and copolymers and butadiene styrene latices in the organic chemicals field, and resin-impregnated fiber battery separators for the automotive storage battery industry.

Circle 77 on Reader Service Card

The Electronic Research Associates, Inc., announces the availability of a new issue of their four-page, two-color catalog 114A, which describes their Magitran line of solid state regulated power supplies. These supplies combine the features of magnetic and transistor regulators. The catalog sheet provides information on several new intermediate current units, as well as new specification data on high current models, and full descriptive material, graphs, specifications, physical data and related information.

Circle 78 on Reader Service Card

Two-color data sheet gives detailed techanical data on Arnold Magnetics Model 591J transistorized regulated power inverter. Unit is used to drive A.C. gyros and other A.C. devices from a battery source. The text describes a circuit which eliminates the tendency of A.C. gyro spin motors to hunt when near synchronous speed. Also described is a short circuit and input over-voltage protection feature. Three terminations are listed as standard—A/N Cannon connector, wire-lead pigtail, and solder-lug terminals.

Circle 79 on Reader Service Card

Matthew Laboratories Constant Current and Constant Voltage Automatic Switchboard Regulated Power Supplies are described in Bulletin HVVC-95. These supplies are available in a wide range of control configurations and power outputs into the KVA range.

Circle 80 on Reader Service Card

A new technical brochure just published by Technitrol Engineering Company illustrates and describes its standard line of low power pulse transformers and electronic test instruments. The four-page brochure lists all physical and electrical specifications on Types M, P and T Series transformers and includes a list of stock item units along with prices for quantities from 1 to 99. Also included are some technical application notes on the use of the transformers as blocking oscillators or for interstage coupling for both vacuum tube and transistor circuits.

Circle 81 on Reader Service Card

Dialight Corp., offers an 8-page 2-color Brochure on Datalites—the Ultra-Miniature Indicator Lights made by Dialco for use in data-processing equipment, computers, and automation applications. Two basic styles are discussed: (1) Datalites with built-in lamps which are not replaceable . . . (2) Datalites with Dialco's own Lamp Cartridges which are replaceable. Also described are Datalites with female receptacles for AMP "53" Series Taper Pin Terminals.

Circle 71 on Reader Service Card

Lel, Inc., Catalog #95 provides 16 pages of information on I.F., R.F., and TWT amplifiers for radar and missile use. Information is included on electrical characteristics, mechanical construction, and general application. Several new transistorized units are described, including a hybrid strip combining tubes and transistors for minimum noise figure and power consumption.
Circle 60 on Reader Service Card

The 20-page, fully illustrated booklet Rhodium Electroplating Processes, of which 10,000 copies were distributed on request in less than a year, has been revised and reprinted by Sel-Rex Corporation. The booklet tells when, where and how to use rhodium electroplate to improve product performance and reliability in electrical, electronic and other industrial applications. A wide range of rhodium's decorative applications are also discussed and evaluated.
Circle 61 on Reader Service Card

The new condensed catalog of semiconductor devices—TE-1340A—provides a rapid reference source and features a listing of all basic silicon and germanium products from the Transitron line. Package photos of the various components accompany accurate data charts which supply information regarding the actual range of performance of each device. A concise description of the component type—be it transistor or diode, capacitor or regulator—underlines the significant features as they relate to various aspects of individual application.
Circle 62 on Reader Service Card

Ultrasoundings, a new quarterly illustrated review of ultrasonic progress, has been launched by Acoustica Associates, Inc., manufacturers of ultrasonics systems. The first issue includes several feature articles describing ultrasonic cleaning applications in industry and informs users how to get the most from this fast-growing industrial processing technique. In addition, the publication includes brief descriptions of recent new developments by Acoustica.
Circle 63 on Reader Service Card

A new four-page bulletin E-285, from CBS Electronics gives formulae for designing transformers for use in transistorized power supplies. It offers a handy guide to selecting the proper transistors, choosing operating frequencies, and determining the values of biasing resistors. The bulletin was written by Robert Tomer.
Circle 64 on Reader Service Card

Good-All Electric Manufacturing Company has announced the publication of a new 46 page general Capacitor Catalog. It covers their entire line of Tubular, Ceramic Disc and Subminiature Electrolytic Capacitors and is one of the most complete ever published. Engineers will find it of great technical value.
Circle 65 on Reader Service Card

The Electronic Chemicals Division of Merck & Co., Inc., has issued a Technical Service bulletin describing Merck Thermoelectric Materials. Data is given on Thermoelectric Effects, Thermoelectric Cooling, Bismuth Telluride, Thermoelectric Power Generation and Lead Telluride.
Circle 82 on Reader Service Card

Conrad, Inc., environmental test chamber manufacturer, offers a series of conversion charts and technical data covering altitude pressure and temperature from —5000 feet altitude to 1,800,000 feet altitude in accordance with ARDC model atmosphere. Also included is centigrade to fahrenheit conversion factors from absolute 0 to 1000 degrees and several conversion factors for material, heat, velocity, and vacuum. Two other charts list dry bulb and temperature differential for relative humidity.
Circle 66 on Reader Service Card

A 32-page catalog describing the new Freas constant temperature cabinets is available from the Precision Scientific Company. Fourteen types of cabinets including ovens, incubators, sterilizers and special purpose models are listed in the new catalog along with complete specifications, performance data and price information. Six pages are devoted to maximum safety models. The catalog also includes detailed descriptions of the new Freas features such as electronic control, advanced styling, and black heat heater banks. Another section is designed to assist users in the proper selection of a constant temperature cabinet to meet any particular work requirements. Complete accessory information is also included.
Circle 68 on Reader Service Card

Newly revised, 8-page power supply Bulletin 765C describes a complete line of power supplies for laboratory and control use. Included are some interesting application diagrams and descriptions for using programmable power supplies in automatic test equipment. Physical and electrical characteristics are listed. Electronic Measurements Co.

Circle 69 on Reader Service Card

Specifications of most U. S. Semcor diodes have been compressed to fit on one folded sheet of paper for ready reference, according to an announcement by J. C. Worth, Jr., sales vice president. This new "Short Form Catalog" contains the basic information wanted by engineers, together with 1N numbers and brief descriptions of the various lines. The catalog lists temperature compensated voltage regulating diodes, alloyed junction low power zener diodes, diffused junction medium power zener diodes, alloyed junction low power rectifier diodes, diffused junction medium power and commercial rectifier diodes, high voltage rectifiers, double anode diodes, solid tantalum capacitors, and tables of ordering information.

Circle 70 on Reader Service Card

A new, four-page catalog, Form 1895, on silicon glass diodes is now available from Silicon Transistor Corp., manufacturer of silicon diodes and power transistors. The two-color spec sheet lists some of the firm's high reliability general purpose and fast switching diodes and includes curves, charts and other pertinent data.

Circle 67 on Reader Service Card

Trinity Equipment Corp., offers Bulletin DD-180 on their Heat-Les Dryer Dynamic Dehumidifiers for Compressed Gases. Lists features of Wall Mounted Midget Dryers, Floor Mounted Dryers, advantages of Heat-Les Dryers and method of operation. Also lists data on Standard Heat-Les Dryers.

Circle 83 on Reader Service Card

A data sheet on rare earth metals, containing a price list of twelve of them, has been prepared by the Research Chemicals Division of Nuclear Corporation of America and is now available. The prices are for delivery in ingot or lump form, and are based on actual weight shipped, for the following rare earth metals: Yttrium, lanthanum, cerium, praseodymium, neodymium, samarium, gadolinium, terbium, dysprosium, holmium, erbium and ytterbium. Other types of data on these metals and, in addition, on scandium, europium, thulium and lutetium, are also included.

Circle 84 on Reader Service Card

A data sheet on RF Chokes with unprecedented subminiature characteristics is available from Essex Electronics. The new RF Chokes, called Wee-Ductors, are so small that 200,000 can be packed to a cubic foot. The data sheet contains a detailed description of the electrical parameters for the complete line of Wee-Ductors. The sheet lists parameters for 50 units. The Wee-Ductors are encapsulated, non-flammable, have low DC resistance and excellent shielding characteristics, the sheet states.

Circle 85 on Reader Service Card

Index to Advertisers